UNIVERSITY OF CALIFORNIA · COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

THE IMPORTANCE OF CONTINUOUS GROWTH IN BEEF CATTLE

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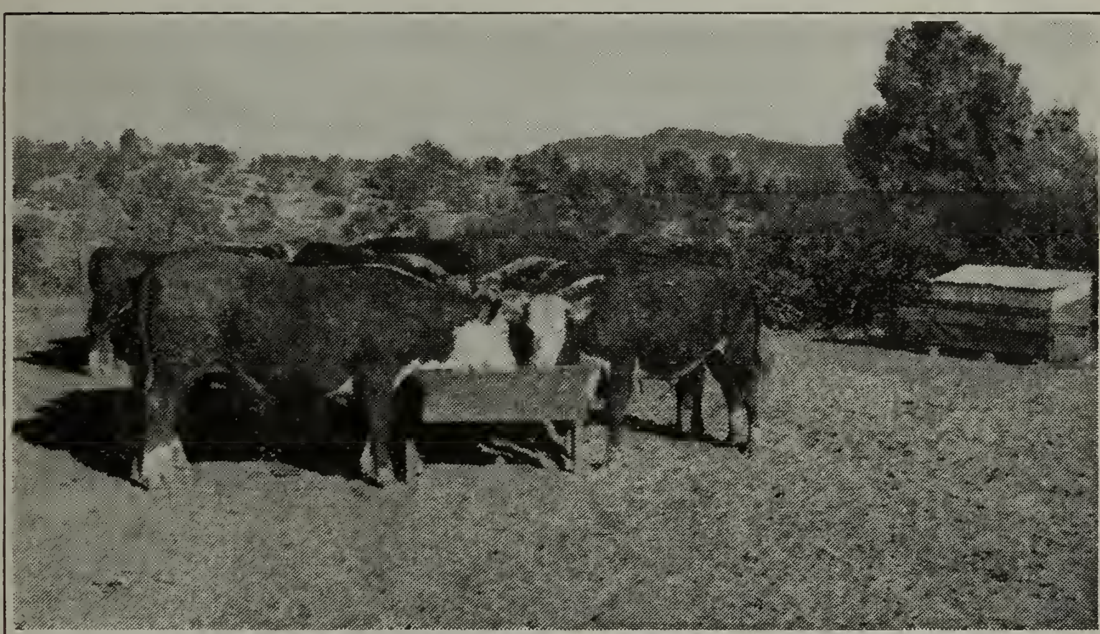

Supplemental feeding on San Joaquin Experimental Range.

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THE IMPORTANCE OF CONTINUOUS GROWTH IN BEEF CATTLE[1,2]

H. R. GUILBERT,[3] G. H. HART,[4] K. A. WAGNON,[5] AND H. GOSS[6]

INTRODUCTION

According to a recent study (Guilbert, Fluharty, and Shepard, 1943),[7] 72 per cent of California's 1942 beef production was derived from range forage, field cleanup, and the hay production that is an integral part of the range-cattle business. Beef cattle utilize and convert into human food the forage production from an estimated 40 million acres of range lands, amounting to 40 per cent of the land area of the state.

A major problem, therefore, confronting beef-cattle producers is how best to utilize the natural vegetation. The fallacy of expanding animal numbers beyond feed supply has become generally recognized because of the difficult problems arising from the war emergency.

The indices to guide operators are the pounds of beef produced per acre, per animal unit, and per man hour, with due consideration for the condition of the range and the well-being of the cattle. As suggested earlier (Wagnon, Guilbert, and Hart, 1942), the concept of maximum forage utilization compatible with maximum production per animal unit might be widely applied in defining the proper rates of stocking from both economic and ecological standpoints.

Efficient meat production and efficient use of range feed involve supplemental feeds. These are supplied during the dry season to furnish specific essential nutrients that become deficient in the natural vegetation. Thus a plane of nutrition may be attained that will promote continuous growth and development—a consideration especially important in young animals at the time when the growth rate is potentially greatest and when live-weight gains are most economical. These principles apply to animals that will be finished on the range and to those that will be sold as feeders for feed-lot fattening. They also apply to breeding herds maintained for high percentage calf crop, adequate milk supply, and heavier weights of calves at weaning time.

If beef ranches are not producing 80 to 85 per cent calf crops, 450- to 500-pound calves at weaning, and 800- to 850-pound steers at yearling age, production efficiency can usually be improved by changes in management and feeding practices.

The data presented cover paired animals fed approximately equal quantities of supplemental feed and carried to approximately equal finish, but fed at

[1] Received for publication March 23, 1944.

[2] This report is part of a project on range livestock management in the granite area of the Sierra foothills. Coöperators in the project are the California Forest and Range Experiment Station, U. S. Forest Service, and the Division of Animal Husbandry, College of Agriculture, University of California.

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[7] See "Literature Cited" for complete data on citations, which are referred to in the text by author and date of publication.

different times so that the growth curves are widely different. The results show strikingly how one can meet problems of production efficiency economically by using supplemental feeds in limited quantities when they are most needed and best utilized by the animals.

REVIEW OF LITERATURE

Space would not permit complete citation of work having a bearing on the present experiment. All experiments on nutrition and production show that with animals, as with machines, factories, or other working units, production is most efficient when operation is proceeding at a rate that approaches full capacity. In the dairy cow or the meat animal, the feed requirement for body maintenance and temperature regulation represents a large part of total feed use. The greater the rate of production (within certain limits) that can be obtained by liberal feeding, the greater is the efficiency from the standpoint of pounds of feed required per pound of resulting product. This may be referred to as biological efficiency. Economic efficiency depends upon relative costs of different phases of production—for example, cost of summer gain on range compared with winter gain on hay or concentrate supplements. These considerations modify the degree of approach to the ideal that may be made under any specific situation. Maintenance for short periods may, in some cases, be justified (Black, Quesenberry, and Baker, 1939). In general, however, very close correlation is found between biological efficiency and economic efficiency as represented by returns in dollars and cents, especially when one takes the broader viewpoint of the lifetime history and performance of the animals.

An extensive fundamental study on the effect of nutritional plane and age on efficiency of feed utilization, development, and composition of the body and the carcass was outlined by Waters and carried out by Trowbridge, Moulton, and Haigh (1915, 1918, 1919; Moulton, Trowbridge, and Haigh, 1921, 1922*a*, 1922*b*). In this work at the Missouri Agricultural Experiment Station, higher planes of nutrition proved to be more efficient from the standpoint of energy recovery and of the recovery of edible meat; undernutrition, resulting in a slow rate of gain, affected the height growth least, the length growth and width at hips to a greater extent; hindquarter development was retarded more than forequarter by undernutrition and stimulated most by a high plane of nutrition. Marked differences, of course, developed in percentage of bone, fat, and lean in the carcasses as a result of different planes of nutrition. Some animals were continued on experiment over a period of three to four years. In these experiments the ration was composed of alfalfa hay, grain, and linseed meal and presumably was nutritionally complete. The total daily allowance, however, was varied to secure the different growth rates desired.

Watson (1943) at University College, London, seeking information basic to wartime food-production policy in England, evaluated the Missouri data thoroughly. He desired to establish the mathematical relations of nutritional plane, age, and weight to efficiency of production. His analysis further emphasizes the physiological efficiency of high nutritional planes. Doubling the food intake over maintenance was shown to increase efficiency 4.8 times. According to Watson's calculations, full-feeding to a weight of 840 pounds live

weight with a carcass fat content of about 22 per cent and a carcass yield of 60 per cent gave highest efficiency if protein return was the sole consideration. Considered on an energy basis alone, a live weight of 1,700 pounds, together with 35 per cent fat in the carcass and a yield of 64 per cent, was most efficient. If both fat and protein were considered in relation to the value indicated by popular preference, then 1,150-pound animals dressing out about 59 per cent had highest efficiency—a weight and yield consistent with common market practice.

Hammond and his co-workers at Cambridge University, England, have attacked in the broadest and most basic manner the problem of efficient production of high-quality carcasses. These workers have covered both wild and domestic species in studies of growth and development. They particularly

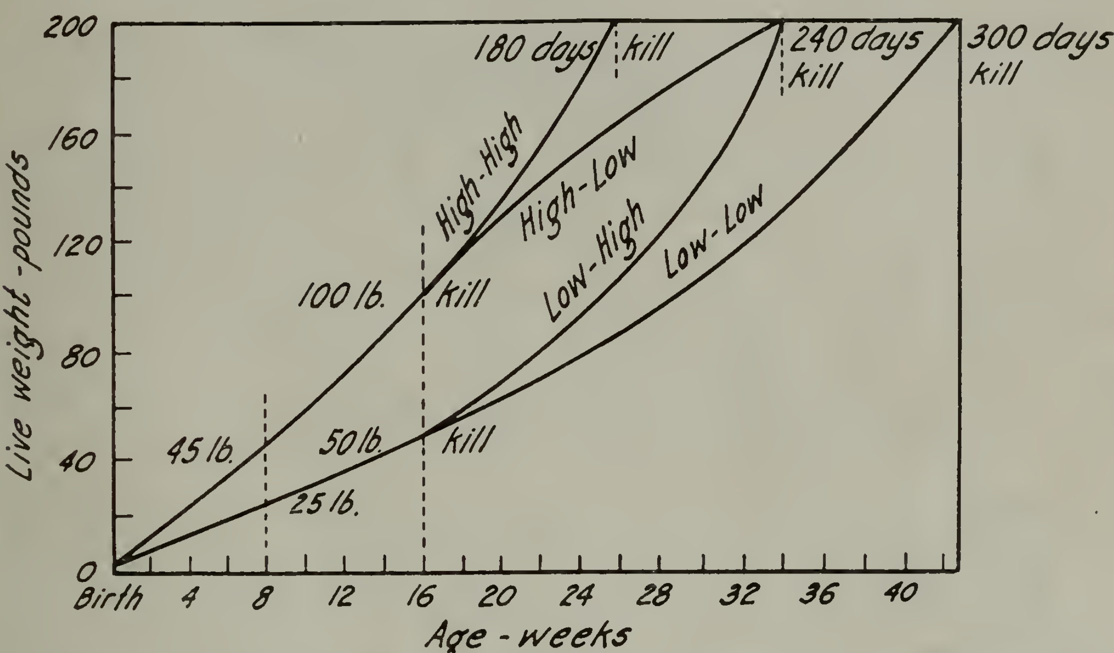

Fig. 1.—Plan of McMeekan's (1940–1941) experiment with swine.

considered, for various parts of the body, the differential growth rates that occur between birth and maturity and result in the difference in body shape of young and adults. Hammond's many years of carcass measurements at the Smithfield Show in London have been coupled with studies of British breeding data. His lifetime investigations of the physiology of reproduction and growth, in which he has followed in the footsteps of two distinguished predecessors, Marshall and Heape, make the Cambridge group the chief center of thought in these subjects.

McMeekan's (1940–1941) recent classic work with swine, in Hammond's laboratory, substantiated and extended the previous work of Verges (1936) with sheep, showing how variations in shape of the growth curve affect the relative development of parts and the composition of the carcass. This work demonstrated that (within limits) one could obtain the desired carcass characteristics either by imposing a nutritional environment in the necessary direction or by changing the strain or breed to an earlier- or later-maturing type.

Figure 1 illustrates the plan of McMeekan's experiments with swine. Litter mates from an inbred strain were selected to minimize genetic variation in the experimental animals. One group, designated as "high-high," was kept

on a high plane of nutrition until the animals reached a slaughter weight of 200 pounds at 180 days of age. A second group, designated as "low-low," was continued on a limited ration and attained 200 pounds weight in 300 days. The plane of nutrition of the other two groups, high-low and low-high, was so regulated that they both reached 200 pounds at 240 days of age, but by different routes. Table 1 shows the differences in carcass composition. The high-high group made the best butcher hogs; the high-low the best bacon carcasses. The low-high group, though it weighed as much at the same age as the litter mates in the high-low group, had an excessive amount of fat in relation to development of muscle. This group had the characteristics of an early-maturing lard type, as compared with the bacon type in the high-low group. The group kept on a low plane of nutrition were long and lean of body; had too high a proportion of legs, head, and neck; showed poor development of loin and hindquarter; and yielded carcasses deficient in fat. Detailed study of the percentage increase in individual bones, muscles, and fat tissue throughout the body demonstrated that in undernutrition the length growth of bones takes priority, for nutrients available, over thickness growth; early-maturing parts (long bones, head, neck, and forequarter) over late-maturing parts such as loin and hindquarter; muscle growth over fat deposition. At 16 weeks of age, for example, the weight of the loin in the high-plane pigs was 450 per cent that in the low plane, and the head was 209 per cent. Similarly the weight of the fat in the high-plane pigs was 1007 per cent that of the low plane, while bone was only 224 per cent. Thus those tissues and parts that develop later in life (such as loin and fat) are stimulated by a rapid rise in the weight-growth curve, whereas the proportion of earlier-maturing parts (such as head and bone) is accentuated by a slow rise of the weight curve.

TABLE 1

VARIATION IN PERCENTAGE COMPOSITION OF CARCASS DEPENDING ON THE SHAPE OF THE GROWTH CURVE

(McMeekan, 1940–1941)

Group	Live weight, pounds	Percentage composition of carcass		
		Bone	Muscle	Fat
High-high	200	11	40	38
Low-low	200	12	49	27
High-low	200	11	45	33
Low-high	200	10	36	44

EXPERIMENTAL PROCEDURE

The Missouri experiments were involved with variations in plane of nutrition, each plane remaining more or less constant for definite periods. In McMeekan's work, final weight was the constant factor. The present experiment was an attempt to follow, with modifications, the pattern of McMeekan's high-high and low-high groups under the environmental conditions of the San Joaquin Experimental Range. This experiment differed in that the high group was fed for continuous but not maximum gain, time was equal for both

groups, and approximately equal fatness was attained at different average final weights. Since desirable market weight is less sharply defined for cattle than for swine and sheep, perhaps equality of finish may be a more practical constant to require in some types of cattle experiments.

Range Area and Forage.—The San Joaquin Experimental Range is located in the so-called granite area of the Sierra Nevada foothills at an elevation of 1,000 to 1,500 feet. The area is characterized by scattered oak and Digger pine trees and brush, with a ground cover consisting largely of annual grasses and herbs. The soil, derived from decomposed granite, is shallow except in swales,

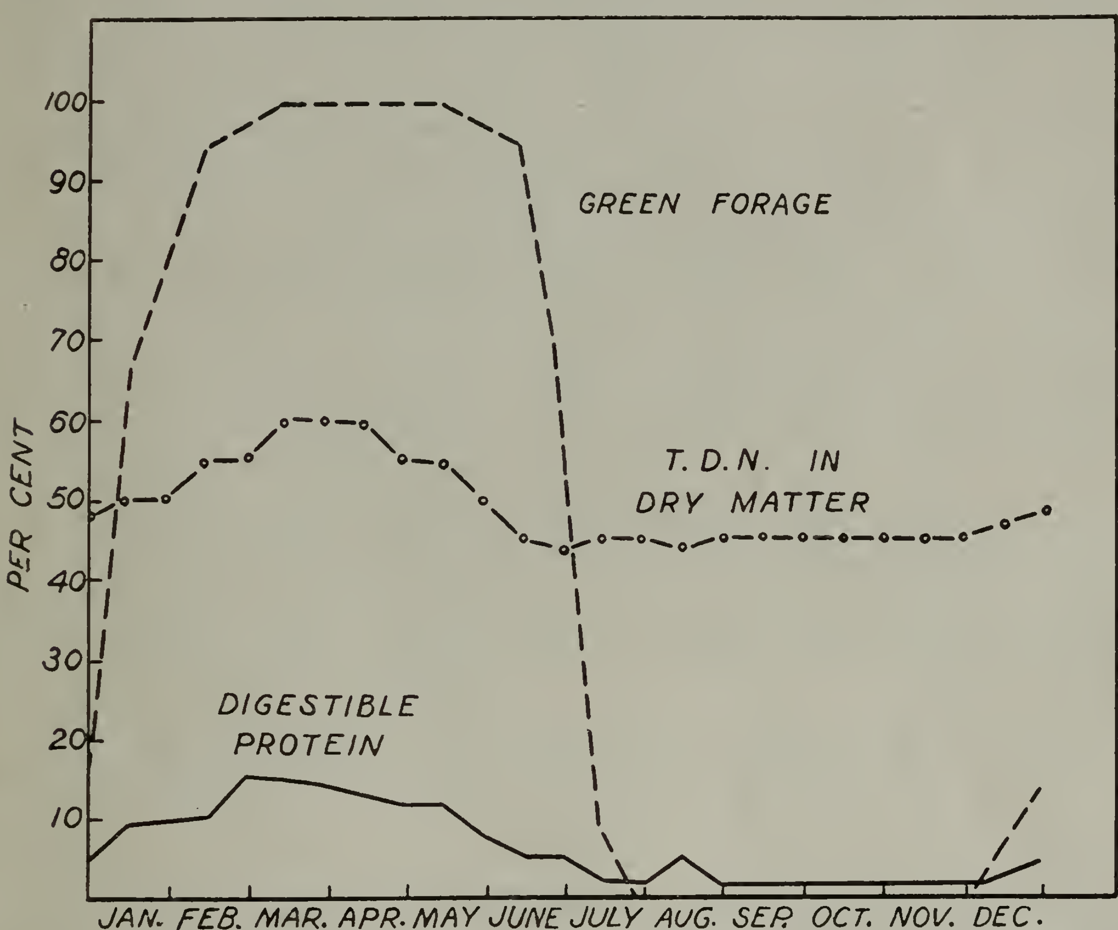

Fig. 2.—Typical seasonal changes in total digestible nutrients and digestible protein in dry matter of the forage as grazed on the San Joaquin Experimental Range, together with an estimate of percentage of green forage consumed.

which constitute a small part of the total area. Rock outcroppings are numerous. The area, the environmental conditions, the forage, and the organization of investigational work are described in detail by Hutchison and Kotok (1942).

The annual grasses and herbs germinate quickly after the first rains, usually in November. Because of low temperature, growth is slow until February. A short period of rapid forage development in March and April is followed by maturing and drying in May and June. The time of forage drying depends on late spring rains and varies from year to year. Swale areas normally remain green into June, and nearly all the forage is completely dry by the first of July. Small quantities of Spanish clover or other late-growing species remain green for a longer period, but are quickly utilized by grazing.

Figure 2 illustrates the typical seasonal changes in the range forage. The curves are based upon chemical analyses of forage samples composited over

2-week periods throughout the year and collected, to represent actual grazing, by following the cattle. Digestibility is based upon digestion trials with similar green forage, together with digestion trials on samples of the dry grass,

TABLE 2

PAIRING OF ANIMALS ON THE BASIS OF AGE, SIRE, GRADE, AND WEIGHTS FROM JANUARY TO JULY, 1941

(The first animal of each pair was placed in group 1; the second in group 2)

Pair and animal nos.	Weight in pounds				Age, days	Sire no.	Feeder grade*
	Jan. 31	April 2	June 9	July 3			
Pair 1:							
02	102	225	380	400	176	635	2–
09	120	235	370	390	183	635	2–
Pair 2:							
03	167	290	420	454	253	604	2
013	179	300	420	460	240	604	2
Pair 3:							
04	179	330	500	531	270	604	2–
012	205	340	485	520	256	604	2–
Pair 4:							
08	159	300	465	490	239	604	2
010	173	300	435	475	228	604	2
Pair 5:							
014	112	230	390	420	209	628	2–
016	123	244	395	420	210	635	2–
Pair 6:							
027	240	340	490	525	267	533	2
032	248	380	520	545	257	533	2–
Pair 7:							
028	200	335	480	525	214	647	2–
05	197	340	495	525	226	635	2–
Pair 8:							
035	213	350	480	520	265	533	2
036	217	325	480	510	254	533	2
Group 1, average	172	300	451	483	237	...	...
Group 2, average	183	308	450	481	232	...	...

* Grade 2 corresponds to U.S. "average choice"; grade 2– to "low choice."

Spanish clover, and dry filaree. Other points were derived from the relation of lignin content to digestibility.[8] These data are for 1937—a favorable year in which there was considerable growth of clovers in the swales and in which late rains promoted the late-growing species.

Except for drying of the forage at an earlier date in some years, the data in figure 2 illustrate the typical nutritive regimen to which the cattle are regularly subjected. When green forage appears it is consumed along with the old crop in increasing amounts, as shown by the green-forage curve. Protein and

[8] Unpublished data of H. Goss and H. R. Guilbert.

total digestible nutrients reach a peak at the height of the growing season and decline as the forage matures. The young green forage alone is more highly digestible than the curves indicate. The trend is modified by the amount of old forage taken with the new. Digestible protein, based on correction of apparent digestibility for metabolic nitrogen (Guilbert and Goss, 1944), declines to between 1 and 2 per cent. The slight rise in August was caused by selective grazing by the animals, which were transferred to the previously ungrazed dry forage containing some of the late-growing green plants and dried legumes.

As shown by Wagnon, Guilbert, and Hart (1942), phosphorus declines with the protein to levels of 0.10 to 0.20 per cent of the dry matter. The protein deficiency during the years thus far studied has apparently been more acute than the phosphorus, since no clinical symptoms of phosphorus deficiency such as significantly lowered blood phosphate have been noted in unsupplemented animals. Calcium content of the herbage is adequate throughout the year. The total digestible nutrients in the dry forage before it is leached by autumn rains are sufficient to permit slow weight gain when protein deficiency is alleviated by protein concentrates that also supply sufficient phosphorus. Previously obtained data (Wagnon, Guilbert, and Hart, 1942) had shown that without supplements all classes of cattle lost weight soon after the first of July, regardless of the abundance of feed.

Animals Used.—Sixteen steer calves were selected at weaning time (July 1, 1941) from the Hereford herd on the Experimental Range. They were divided into eight pairs matched as closely as possible for age, weight, consistency of previous gains, sire, grade, and body measurements. Table 2 shows weights, age, sire, and grade of each pair.

The sire was the same for paired animals, except that in pairs 5 and 7 the sires were half brothers of comparable grade and quality.

Weights.—Because of the general impracticability of taking three consecutive daily weights under pasture and range conditions, a single weight was taken at intervals of 25 to 35 days. The initial weight was recorded soon after separation of the calves from their mothers. For subsequent weighing, including May 11, 1942, the animals were driven from near-by pastures to the corrals and weighed full between 8:00 and 9:00 A.M. On and after June 12, weights were taken between 6:00 and 7:00 A.M. after the animals had stood about 12 hours in a corral without feed or water.

In earlier studies,[9] fill (determined by the amount of shrink in 12 hours) increased with forage development to a maximum in May or June, but declined thereafter as the feed dried, became nutritionally deficient, and was rendered relatively unpalatable. Thus gains were exaggerated in the period of increasing fill and minimized (or the losses exaggerated) in the period of decreasing fill. Shrunk weights reduced this systematic error and gave a truer picture of body-weight changes.

Measurements.—At each weighing time the following measurements were taken: height at withers, height at hook bones, heart girth, horizontal length from point of shoulder to a line dropped vertically from the pinbones, length of head at the eye level, and round measurement. This last measurement, pro-

[9] Unpublished data of K. A. Wagnon and H. R. Guilbert.

posed by Gregory (1933), extends horizontally from the point of the stifle (patella) on one side around the thighs to the point of the stifle on the opposite side. The animals were measured in a squeeze-type chute. They soon became gentle (with one exception, no. 012) ; little difficulty was encountered in securing normal stance and satisfactory measurements. Previous culling of the wild cows, together with careful handling of the cattle, had resulted in a remarkably tractable herd.

Photographs.—A photographic chute was constructed as illustrated in figure 3. Photographs were taken at each weighing time both on black-and-white and on color film. The latter was used for lantern slides and for checking or securing additional measurements when projected at one third life size. The

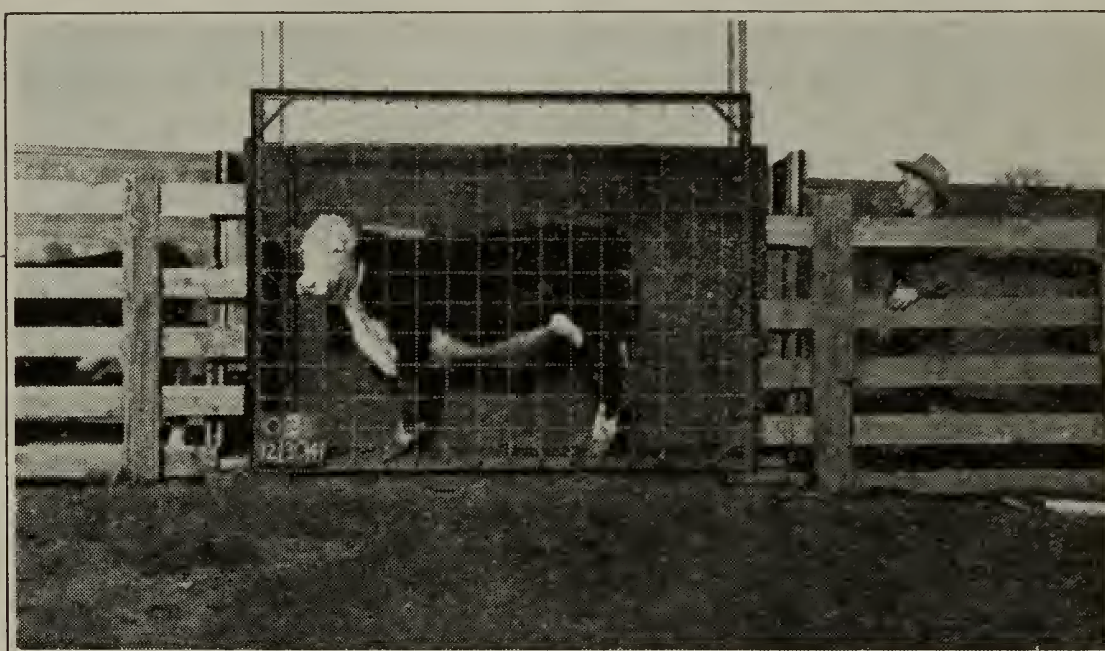

Fig. 3.—Chute used to photograph animals. The grid wires are spaced 15 centimeters apart.

cross wires of the chute were spaced 15 centimeters apart. The cameras were set up each time on the same spot, on a line intersecting at right angles the center of the chute, and at a distance of 8 meters (about 26 feet). After the first animal had been photographed, it was held immediately in front of the photographic chute, and its presence tended to alleviate any nervousness in the animal being photographed. Animal 012 (whose mother was wild) never became quiet; after he had twice broken the cross wires, the attempt to photograph him was abandoned. The remainder of the steers gave little trouble after the first time, and it was comparatively easy to secure a pose that was normal.

Feeding.—After being separated from their dams, the steers of both groups were held in corrals for a few days until they were weaned. During this time they were taught to eat rolled barley and a cottonseed cake that was 43 per cent protein. Next, the groups were separated and placed in adjacent 90-acre pastures furnishing comparable amounts and quality of dried feed, which had not been subjected to grazing during the growing season. Group 1 was fed supplements for the purpose of producing daily gains of 1.00 to 1.25 pounds until January 1, 1942 (period I). Group 2 received no supplements

during this time and lost weight. Supplements were then given to group 2; and group 1 was allowed to rely on forage alone, which at this time consisted of a mixture of old forage and new green growth. Group 2 ate supplements readily during the early part of period II, while green forage was short and high in moisture. Consumption declined, however, as the forage im-

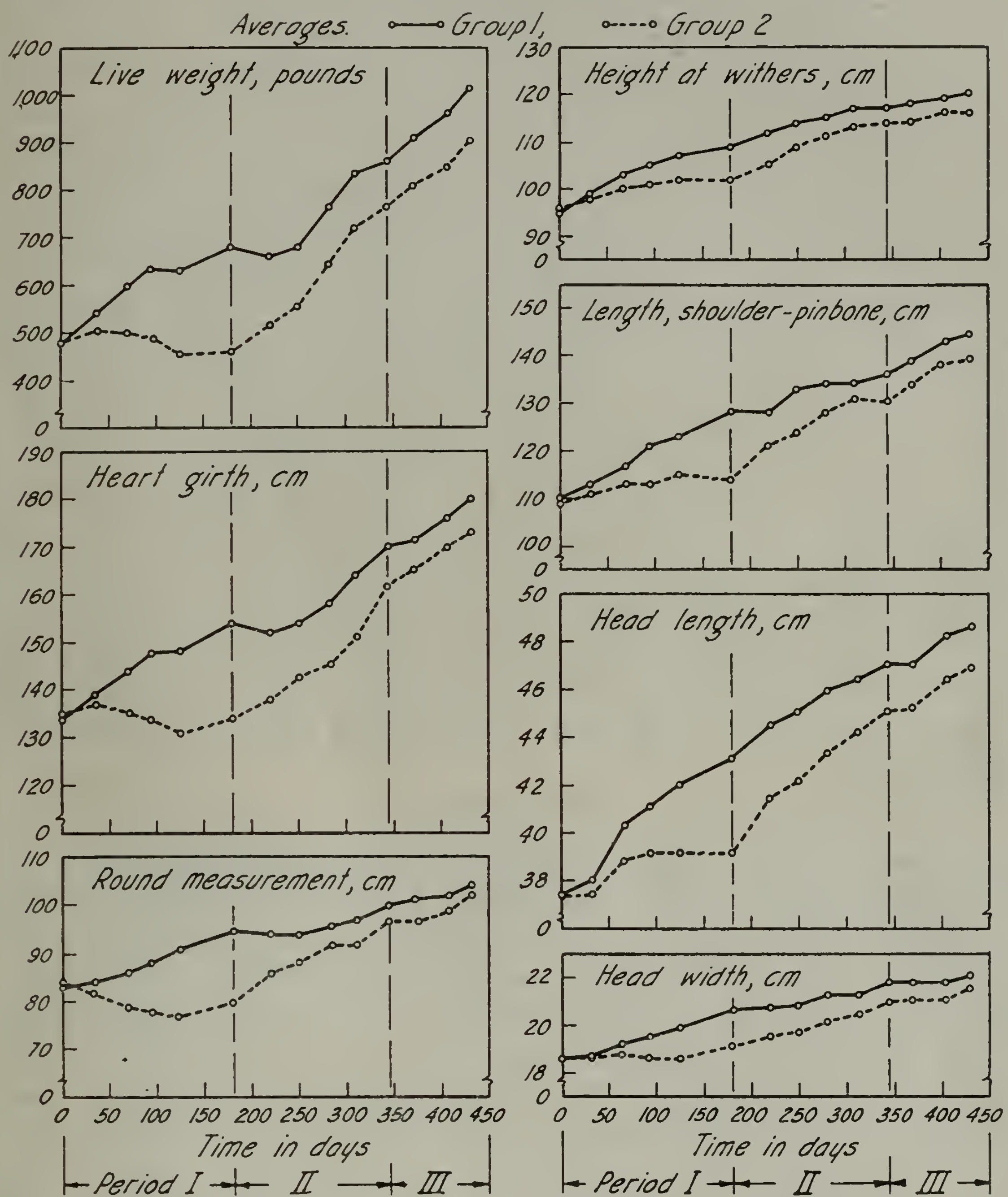

Fig. 4.—Average growth curves of groups 1 and 2.

proved. Feed intake again increased with maturing and drying of the forage. In period III, extending from June 13 to September 7, 1942, both groups were full-fed concentrates in the pastures at the rate of approximately 1 pound for each 100 pounds of live weight. The steers were fed in troughs conveniently located and were trained to come to feed when called. (See frontispiece.) Except for the last 30 days, when twice-daily feeding was employed and the amount increased to 1.5 pounds per 100 pounds live weight, the concentrates were given once daily. When a heavy concentrate ration is fed in a single feed during hot weather, evening feeding was practiced, on the theory that the

resultant peak of body heat production might more readily be dissipated during the cooler nights than during the heat of the day. Empirical observations appear to justify this practice.

Table 3 gives the details of feeding throughout the experiment.

Marketing, Slaughter, and Carcass Studies.—The steers were brought from their pastures to the corrals and weighed just before being loaded on the truck at 3:00 P.M., September 14. They arrived in the South San Francisco Union Stock Yards at 3:00 A.M., September 15. They were allowed feed and water; were sold and weighed about 10:00 A.M. of that day. They were purchased by Swift and Company, the buyer having attempted to evaluate the individual animals as closely as possible. They were slaughtered on September 17, the carcasses individually identified, and the warm dressed weights obtained. The carcasses, graded and stamped by official graders, were purchased by the Safeway Stores and were transferred to their aging and distributing plant on September 21. On September 24 the carcasses were weighed, the left sides were cut into wholesale cuts, and each cut was weighed. The cutting was done by a Safeway crew. All the ribs were left on the forequarter. The cuts were whole round including rump, whole loin including flank, prime rib, shin and shoulder (shoulder removed at the joint and including the cross arm cuts), chuck including neck, and long plate including plate and brisket. After cutting and weighing of the individual wholesale cuts, a sample consisting of the 12th and 13th rib cuts was taken from each carcass. These rib cuts were brought to Davis, the edible portions separated from the bone, and weights obtained on meat and bone. The fat and lean from each rib cut were run twice through a grinder and thoroughly mixed; and a sample was taken for analysis of fat and water content.

RESULTS

Figure 4 presents the average growth curves of each group in terms of live weight, heart girth, height at withers, length of body, round measurement, and head length and width. Plates 1 to 7 inclusive are photographs of each pair of steers, except nos. 04 and 012, taken 5 weeks after the beginning and at the end of period I and at the close of the experiment. Figures 5 to 8 inclusive show the same measurements as figure 4, except those on the head, for each pair of steers. Some of the more important group-average data appear in table 4. Table 5 shows in detail the carcass data and the percentage of lean, fat, and bone in the rib cuts. In tables 4 and 5, where the difference between group averages of basic data are statistically significant the figures are printed in italics.[10] Table 6 compares the live and carcass grades and individual live-weight prices with data on percentage fat in the rib cut and on carcass-value variation due to grade and conformation.

[10] Statistical analysis of the data was made by Dr. G. A. Baker, Junior Statistician in the Experiment Station. Probability, P, for difference between various items was as follows: final weight 0.01; carcass weight 0.06, $\frac{P}{2} = 0.03$; final heart girth, height, length (shown in fig. 4) 0.06, $\frac{P}{2} = 0.03$; percentage fore and hindquarter, 0.05. The statistician felt justified in considering the items where $\frac{P}{2}$ is shown as significant, since they were highly correlated with characteristics such as final weight that were highly significant. Other differences may be real, but there are insufficient data for decisive demonstration.

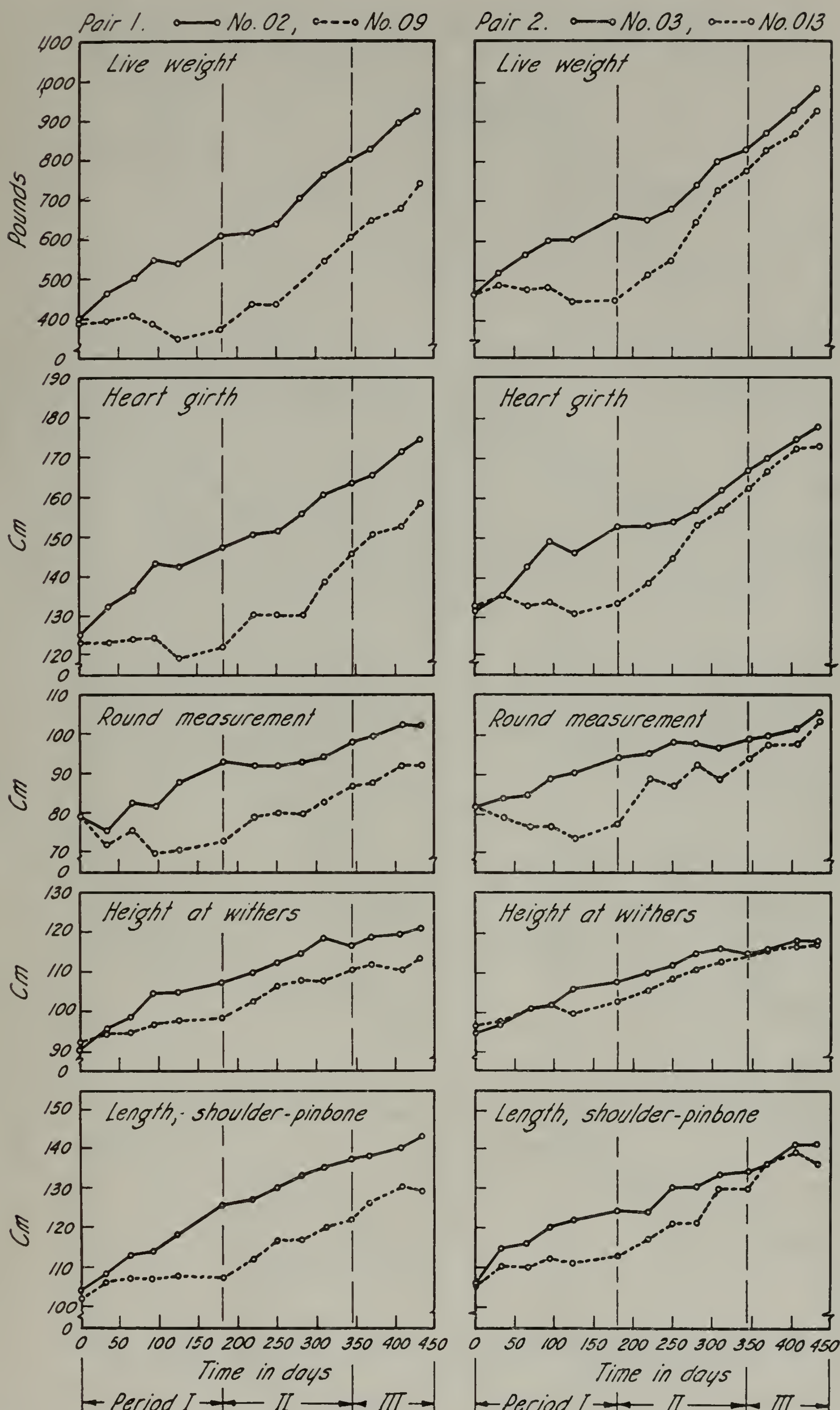

Fig. 5.—Individual growth curves: pair 1, animals 02 (group 1) and 09 (group 2); pair 2, animals 03 (group 1) and 013 (group 2).

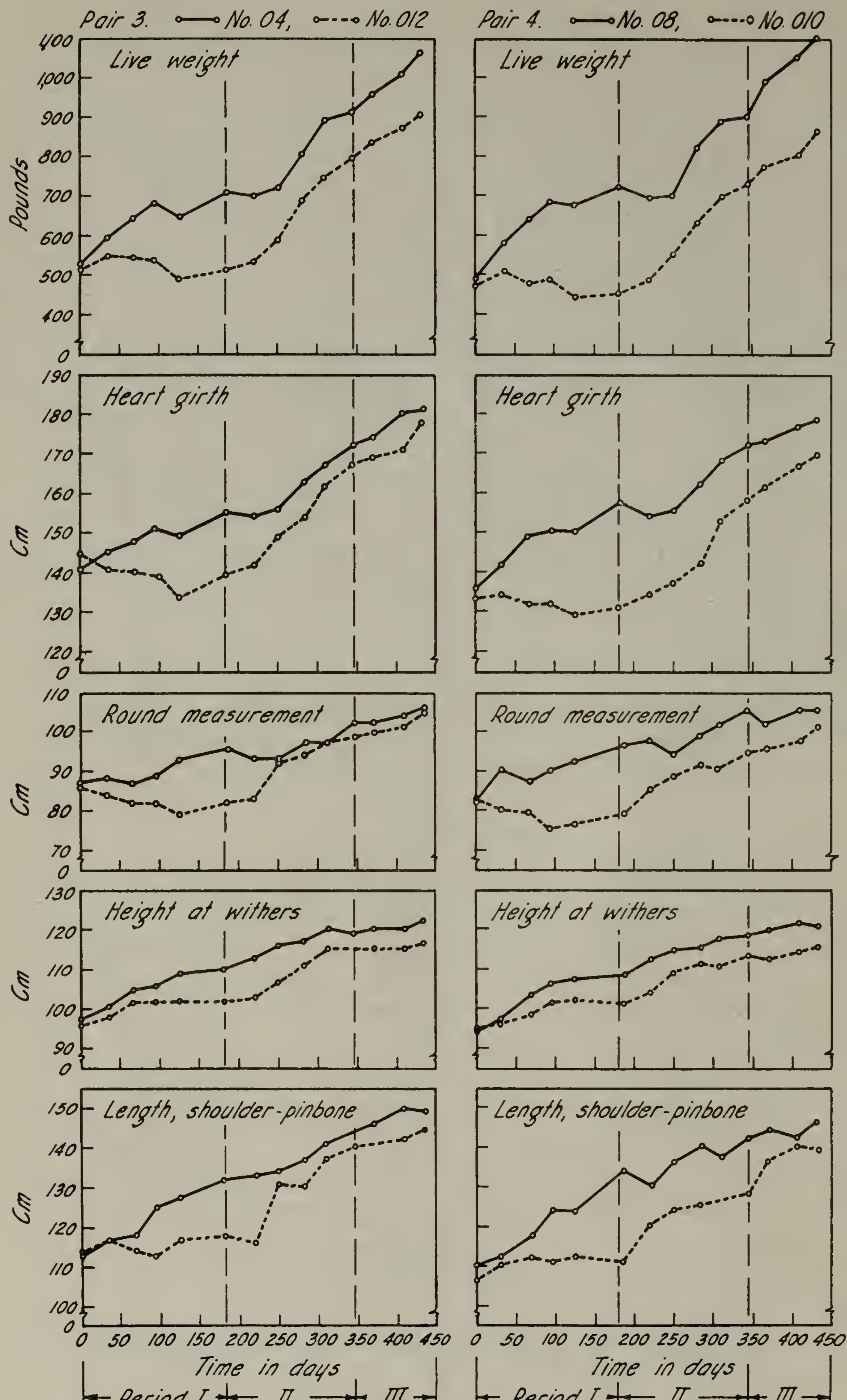

Fig. 6.—Individual growth curves: pair 3, animals 04 (group 1) and 012 (group 2); pair 4, animals 08 (group 1) and 010 (group 2).

PLATES

NO. 02, GROUP 1 NO. 09, GROUP 2

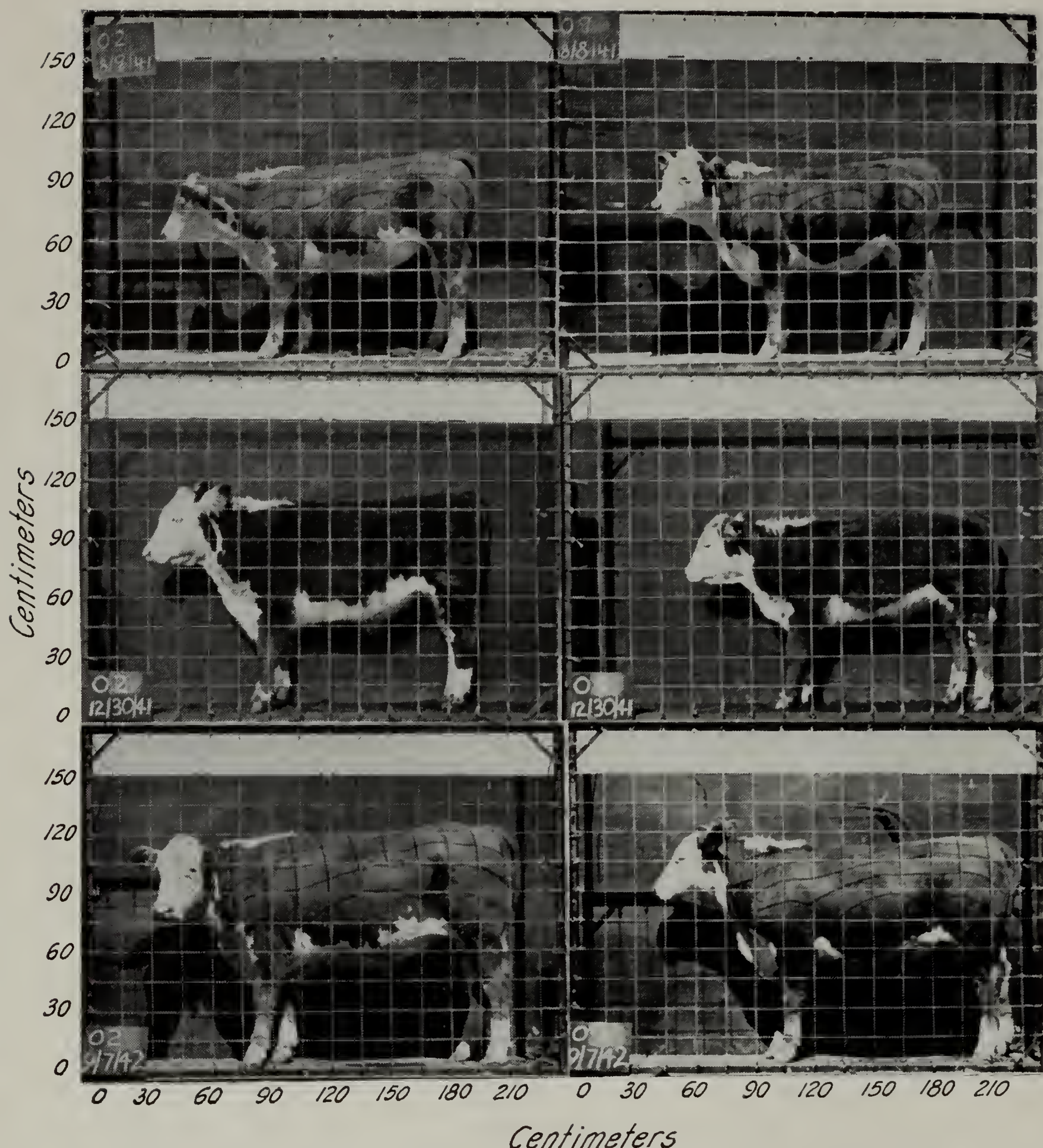

Plate 1.—Pair 1, animals 02 (group 1) and 09 (group 2). Top, photograph taken 5 weeks after the experiment began; middle, at the end of period I; bottom, at the end of the experiment.

Carcass of no. 02: grade, low good; yield, 58.4 per cent. No. 09: grade, commercial; yield, 55.9 per cent.

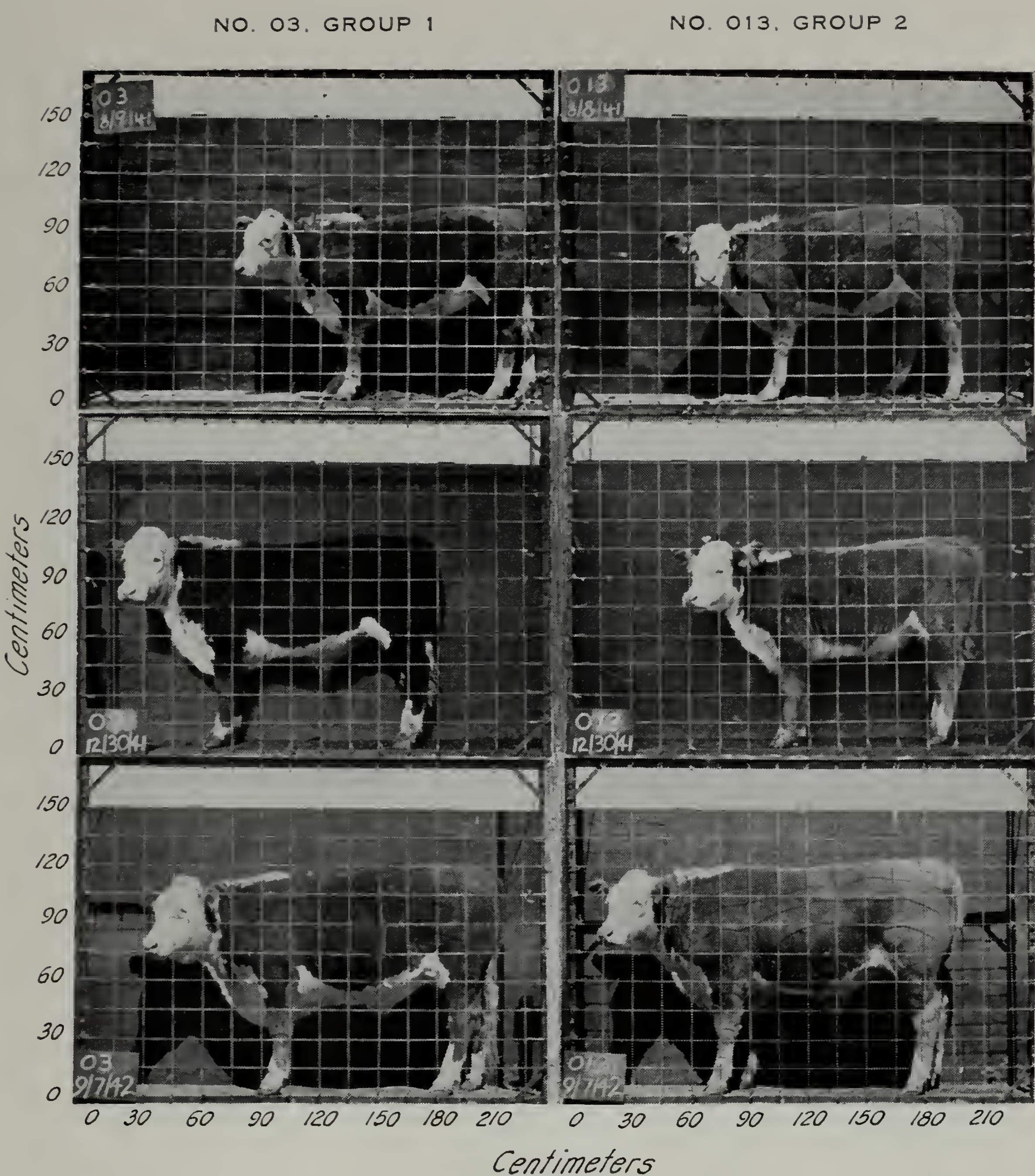

Plate 2.—Pair 2, animals 03 (group 1) and 013 (group 2). Top, photograph taken 5 weeks after the experiment began; middle, at the end of period I; bottom, at the end of the experiment.

Carcass of no. 03: grade, top good; yield, 60.9 per cent. No. 013: grade, good; yield, 60.4 per cent.

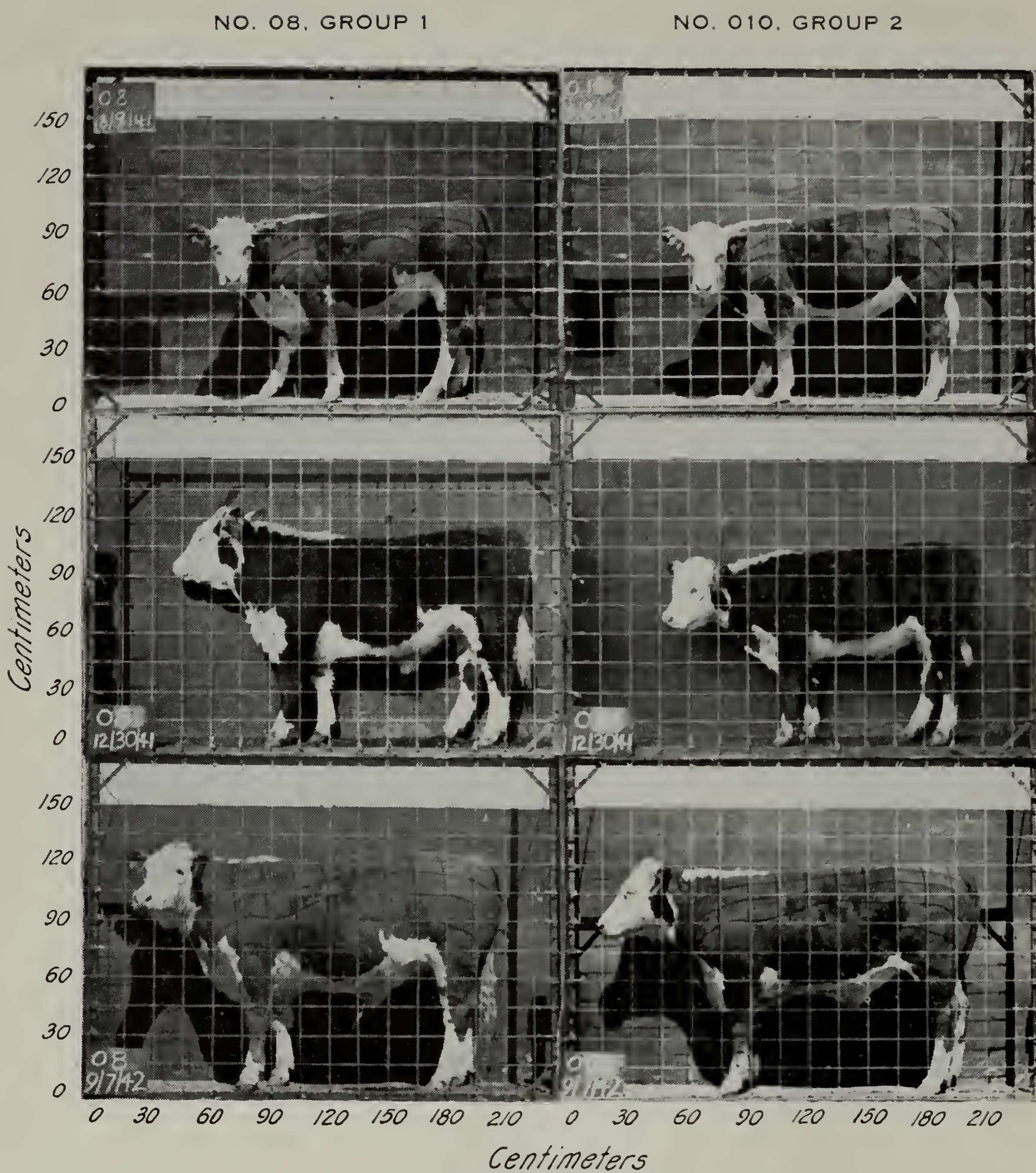

Plate 3.—Pair 4, animals 08 (group 1) and 010 (group 2). Top, photograph taken 5 weeks after the experiment began; middle, at the end of period I; bottom, at the end of the experiment.

Carcass of no. 08: grade, good; yield, 58.7 per cent. No. 010: grade, commercial; yield, 59.9 per cent.

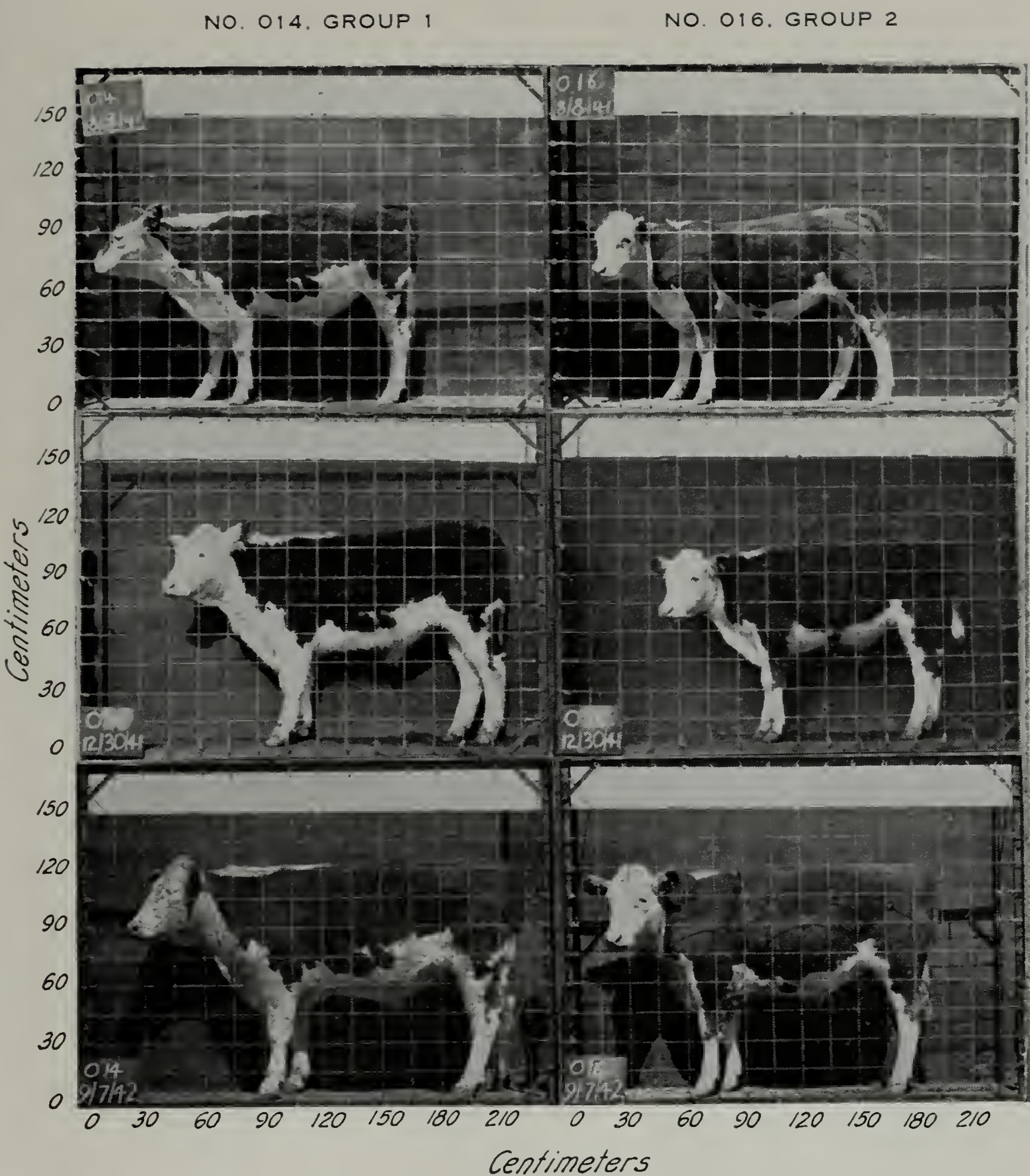

Plate 4.—Pair 5, animals 014 (group 1) and 016 (group 2). Top, photograph taken 5 weeks after the experiment began; middle, at the end of period I; bottom, at the end of the experiment.

Carcass of no. 014: grade, commercial; yield, 58.2 per cent. No. 016: grade, commercial; yield, 58.7 per cent. At time of slaughter, these animals were on the borderline between good and commercial grades.

NO. 027, GROUP 1 NO. 032, GROUP 2

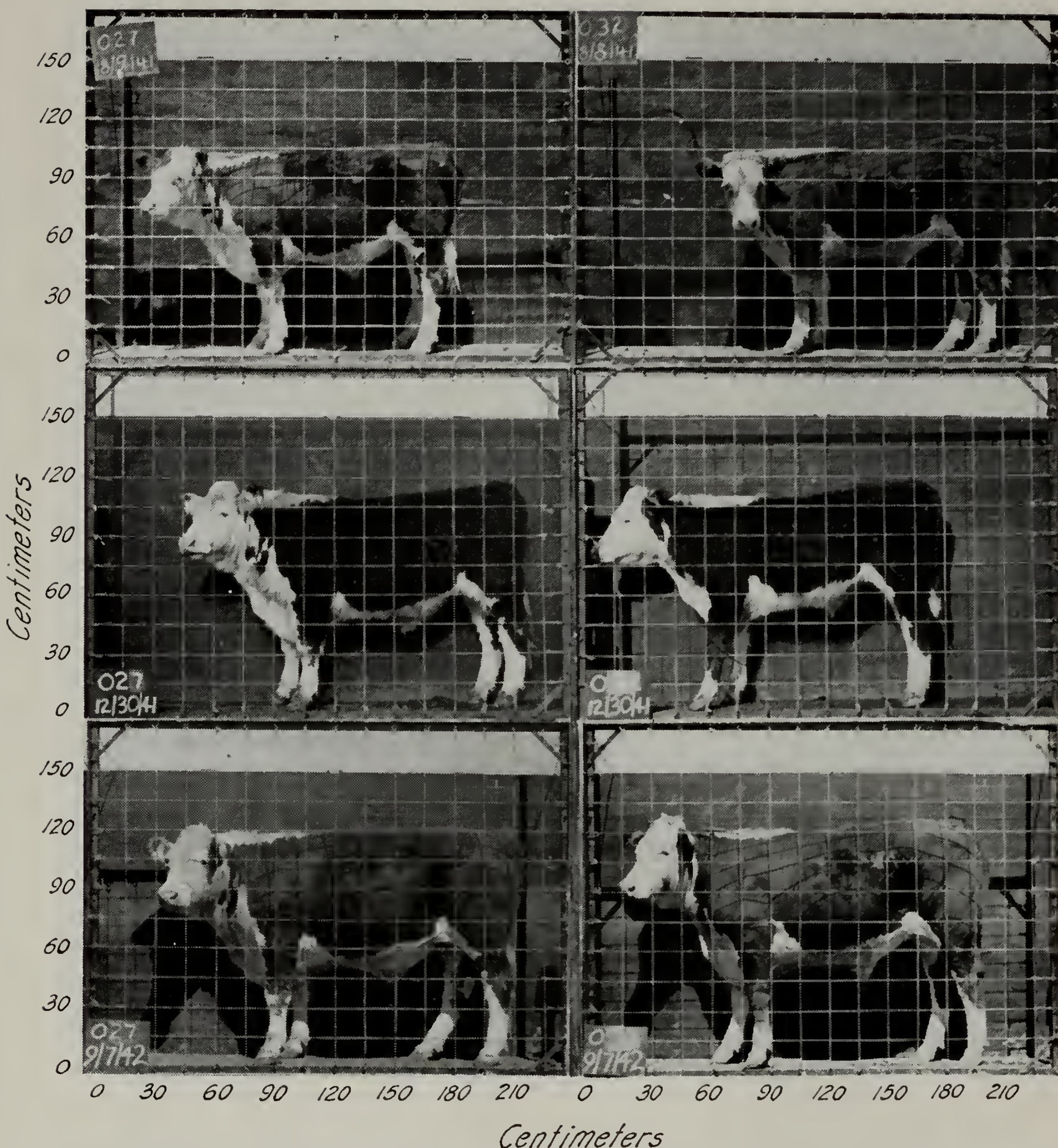

Plate 5.—Pair 6, animals 027 (group 1) and 032 (group 2). Top, photograph taken 5 weeks after the experiment began; middle, at the end of period I; bottom, at the end of the experiment.

Carcass of no. 027: grade, good; yield, 59.4 per cent. No. 032: grade, good; yield, 62.2 per cent.

NO. 028. GROUP 1

NO. 05. GROUP 2

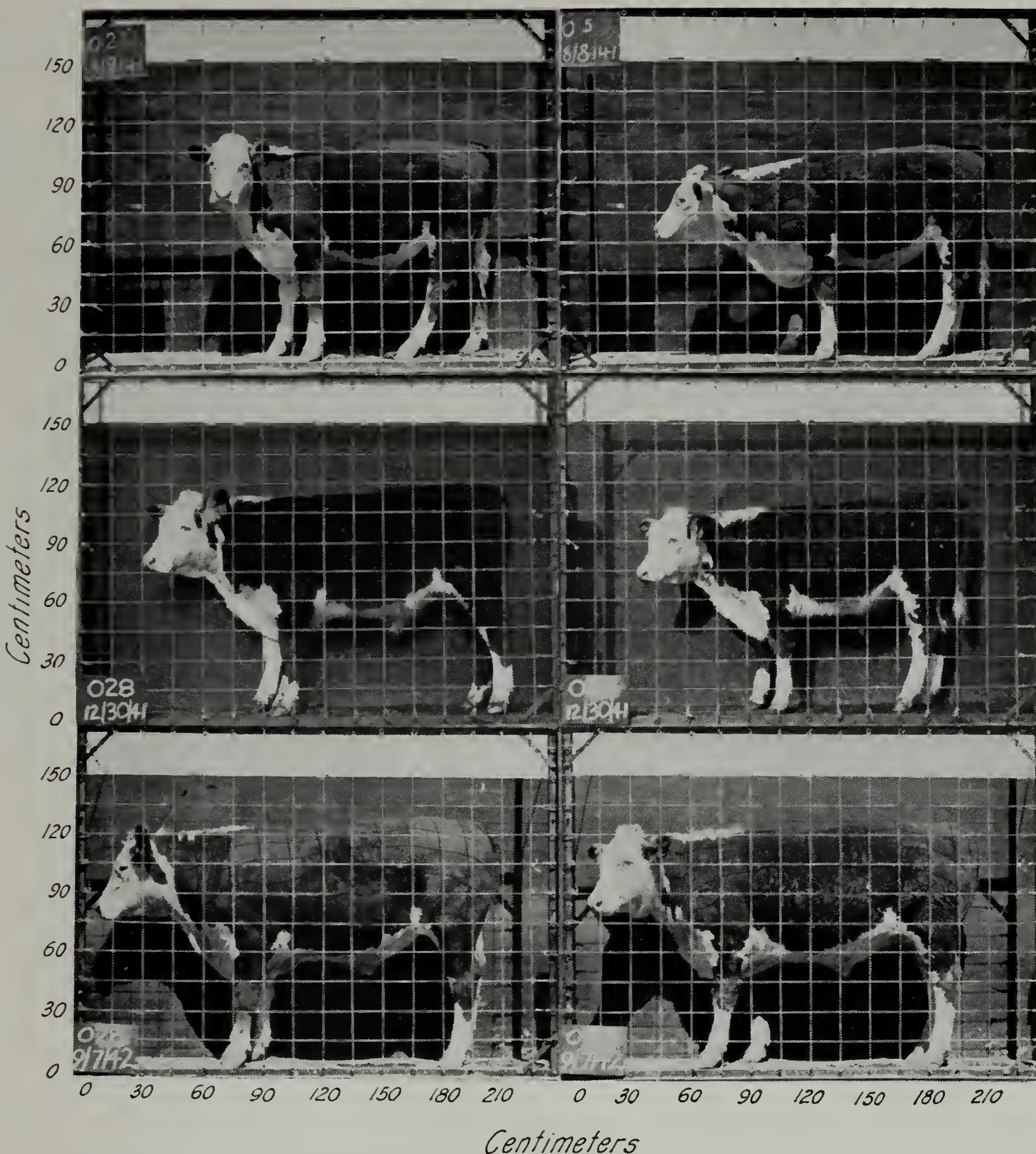

Plate 6.—Pair 7, animals 028 (group 1) and 05 (group 2). Top, photograph taken 5 weeks after the experiment began; middle, at the end of period I; bottom, at the end of the experiment.

Carcass of no. 028: grade, good; yield, 58.5 per cent. No. 05: grade, good; yield, 60.5 per cent.

NO. 035, GROUP 1 NO. 036, GROUP 2

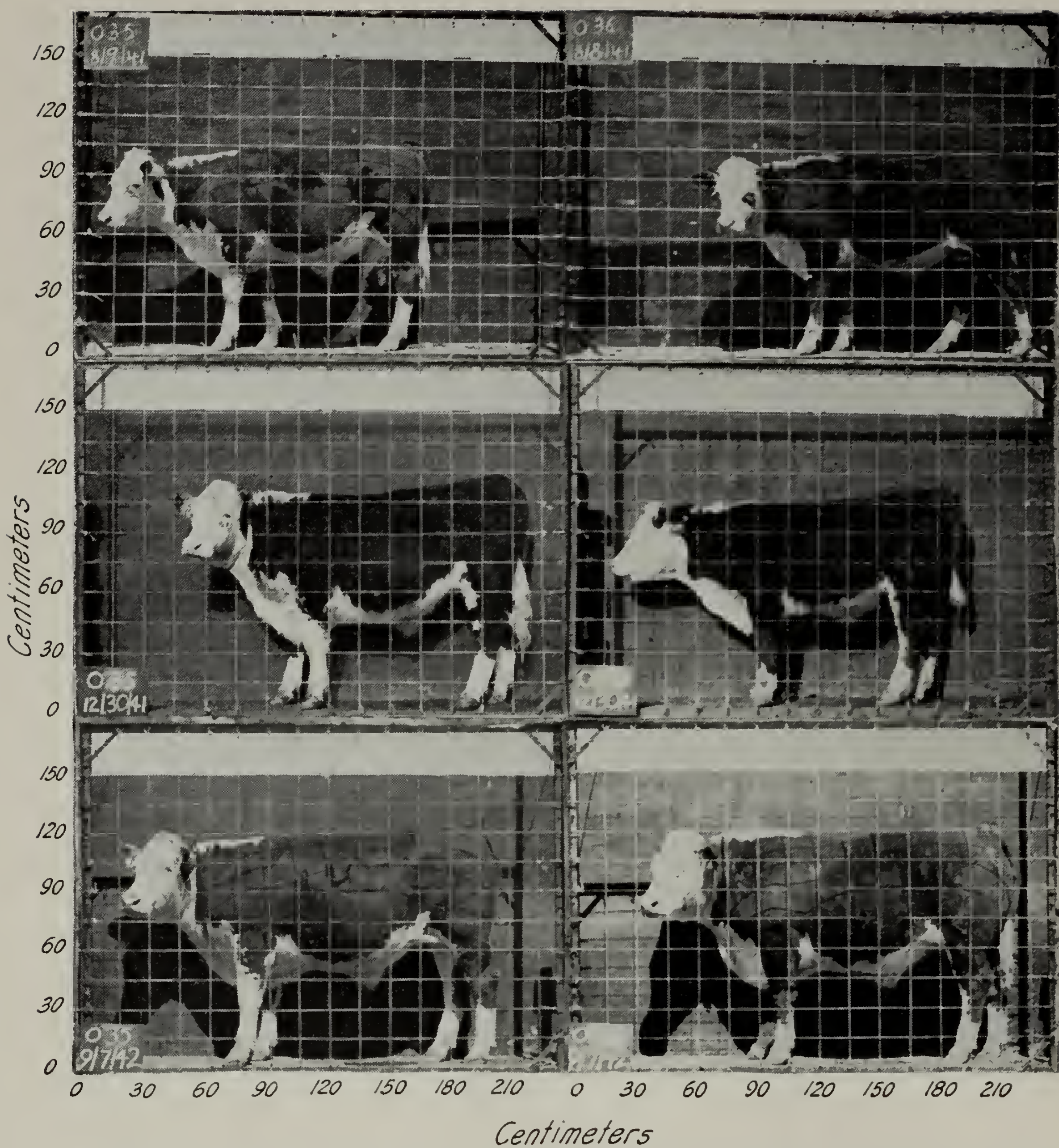

Plate 7.—Pair 8, animals 035 (group 1) and 036 (group 2). Top, photograph taken 5 weeks after the experiment began; middle, at the end of period I; bottom, at the end of the experiment.

Carcass of no. 035: grade, commercial; yield, 59.3 per cent. This animal, as shown above, had the appearance of a good-grade slaughter steer; but distribution of fat covering over the round and inside the ribs apparently was inadequate in the opinion of the grader. No. 036: grade, good; yield, 60.3 per cent.

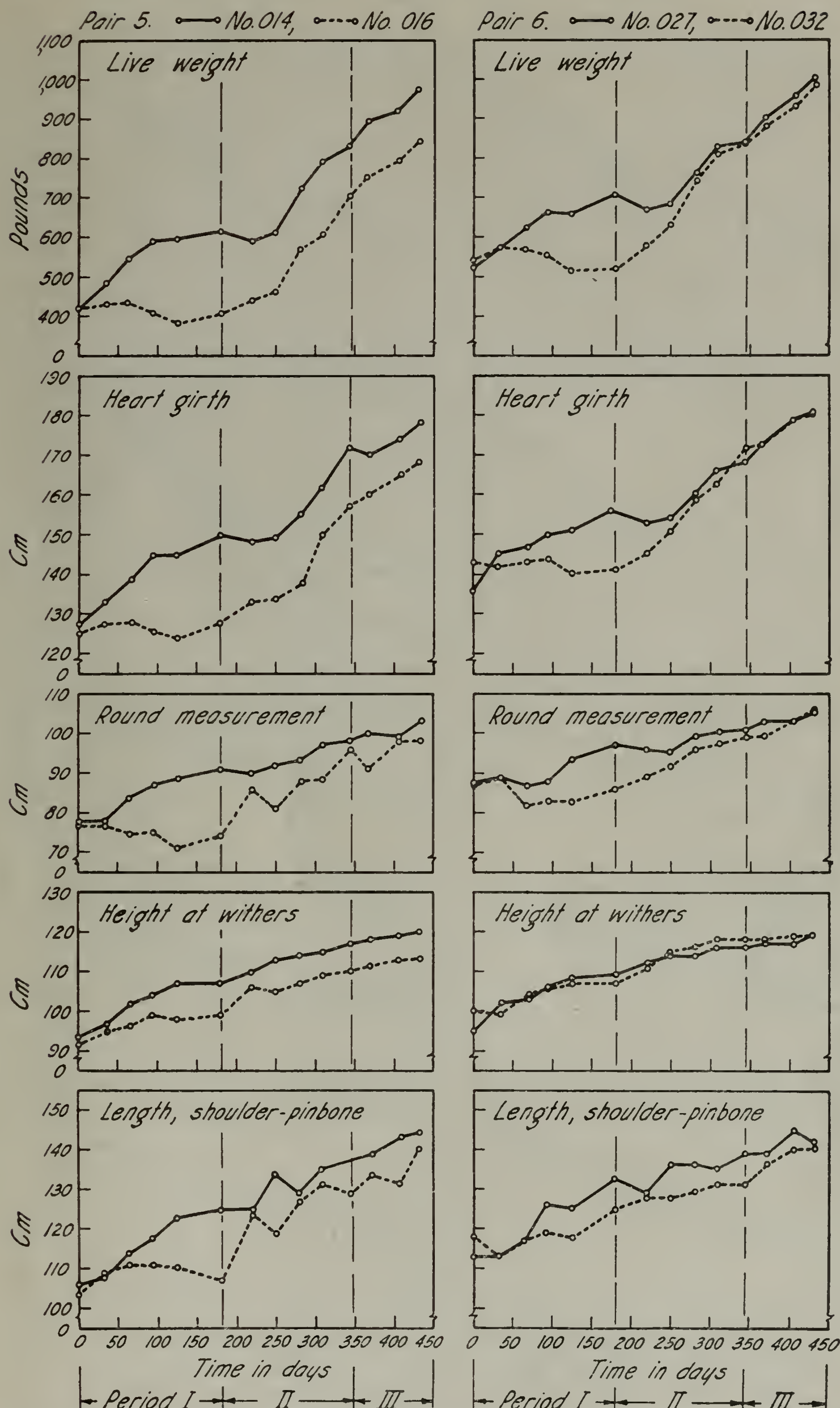

Fig. 7.—Individual growth curves: pair 5, animals 014 (group 1) and 016 (group 2); pair 6 animals 027 (group 1) and 032 (group 2).

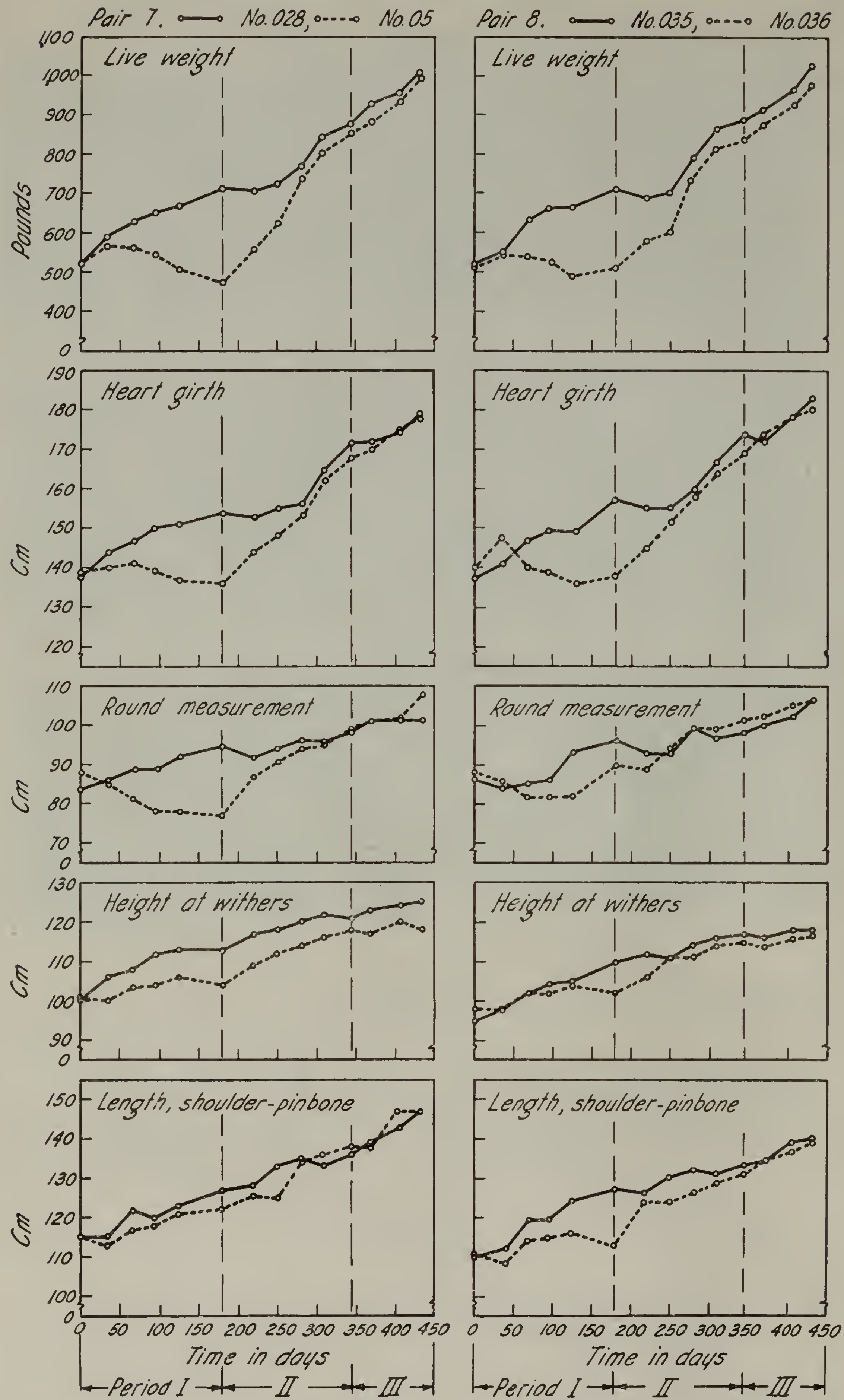

Fig. 8.—Individual growth curves: pair 7, animals 028 (group 1) and 05 (group 2); pair 8, animals 035 (group 1) and 036 (group 2).

TABLE 3

SUPPLEMENTAL FEEDING HISTORY DURING EACH WEIGHING INTERVAL
(Each group had comparable 90-acre pastures)

Interval between weighings, inclusive dates	Group 1, average daily feed, pounds					Group 2, average daily feed, pounds				
	Rolled barley	Cottonseed cake	Ground milo	Molasses beet pulp	Total	Rolled barley	Cottonseed cake	Ground milo	Molasses beet pulp	Total
Period I*										
July 3 to Aug. 5, 1941	1.1	1.1	...	...	2.2	...	...	...	...	...
Aug. 6 to Sept. 8, 1941	1.5	1.5	...	...	3.0	...	...	...	...	...
Sept. 9 to Oct. 6, 1941	1.5	1.5	...	...	3.0	...	...	...	...	...
Oct. 7 to Nov. 6, 1941	2.0	2.3	...	...	4.3	...	...	...	...	...
Nov. 7 to Dec. 30, 1941†	2.0	3.0	...	...	5.0	...	...	...	...	...
Period II‡										
Dec. 31, 1941, to Feb. 7, 1942	...	...	...	...	...	1.8	0.9	1.6	0.9	5.2
Feb. 8 to Mar. 7, 1942	...	...	...	...	...	2.0	1.0	2.0	1.0	6.0
Mar. 8 to Apr. 11, 1942	...	...	...	...	...	1.5	0.4	1.5	1.2	4.6
Apr. 12 to May 11, 1942	...	...	...	...	...	0.6	...	0.6	0.7	1.9
May 12 to June 12, 1942	...	...	...	...	...	1.5	0.6	1.5	1.5	5.2
Period III										
June 13 to July 10, 1942	3.0	1.6	3.0	0.1	7.7	2.0	1.7	2.0	1.6	7.3
July 11 to Aug. 11, 1942	3.5	3.0	3.5	...	10.0	2.8	2.9	2.8	...	8.5
Aug. 12 to Sept. 7, 1942	5.5	2.9	5.5	...	13.9	4.7	3.0	4.7	...	12.4

* Group 2 received no supplements during this period.
† Group 1 was continued at the same rate of feeding until January 11, 1942.
‡ Group 1 received no supplement after January 11.

DISCUSSION

General Considerations.—From the viewpoint of practical operators, the most striking result shown in table 4 is that group 1, fed for continuous growth and development, made 106 pounds more gain and 108 pounds greater final weight, while the total supplemental feed consumption was only 70 pounds

TABLE 4

SUMMARY OF FEEDING TRIAL AND SLAUGHTER DATA
(Average of eight animals in each group)*

	Group 1	Group 2
Weight, pounds:		
July, 1941	483	481
January, 1942	*678*	*461*
June, 1942	*860*	*765*
September, 1942	*1,012*	*904*
Total gain, pounds	*529*	*423*
Total concentrates fed, pounds	1,738	1,668
Feed cost at 2 cents per pound	$34.76	$33.36
Shipping weight, pounds	*1,036*	*923*
Selling weight, pounds	*969*	*868*
Shrink in marketing, per cent	6.4	5.9
Shrink in cooler, per cent	1.65	1.44
Cold carcass weight, pounds	*573*	*521*
Percentage yield of dressed carcass	59.1	60.0
Selling price per hundred pounds	$13.88	$13.48
Selling price per steer	$134.56	$117.05
Hindquarters, per cent of carcass	*48.3*	*47.5*
Forequarters, per cent of carcass	*51.7*	*52.5*
Bone in rib cut, per cent	*14.9*	*15.4*
Fat in rib cut, per cent	32.7	30.9
Lean in rib cut, per cent	52.4	53.7
Lean in fat-free cut, per cent	77.9	77.8
Carcasses, good grade	5	4
Carcasses, commercial grade	3	4
Yields of wholesale cuts	$127.79	$115.02

* Italics indicate that the differences between group averages of basic data are statistically significant.

greater. By reason of the greater weight and average selling price, group 1 (under the cost and price relations obtaining at the time of the experiment) returned $17.51 more per head, though the difference in supplemental feed cost was only $1.40.

In June, 1942, when both groups might have been sold as feeders, group 1 weighed an average of 860 pounds, and group 2 weighed 765 pounds—a difference of 95 pounds. At this time group 1 had consumed 41 pounds less total feed than group 2 (716 pounds compared with 757 pounds). From 40 to 50 days in the feed lot would have been necessary to make up for this difference of 95 pounds in weight between the average of the groups. According to average feed-lot records, the feed required would have been about 400 to 450 pounds each of concentrates and harvested roughage.

The difference in efficiency can be attributed largely to the comparatively small daily allowance of supplement, which permitted productive utilization of the otherwise nutritionally deficient dry forage and reduced the proportion of total feed used for maintenance.

No means were available for ascertaining the amount of range forage actually consumed by the two groups except that they had access to equal-sized pastures of comparable feed. Stocking was at a rate above the average maximum for the area.

Other information has demonstrated that animals on nutritionally deficient diets consume less feed than when the ration is complete. From this we may conclude that group 1 animals actually ate more forage during period I. The fields, however, did not look noticeably different at the end of the period, for feed disappears because of trampling, rodents, and weathering in any event. The principal point is that in two equally stocked fields significant production was induced in one case, actual weight was lost in the other, and the feed disappeared in both.

As data (Wagnon, Guilbert, and Hart, 1942) have shown, 300 to 600 pounds of supplemental feeds given to calves, during periods comparable with period I in this experiment, resulted in weight differences varying from 100 to 255 pounds between them and control animals (receiving no supplement) at the end of the following grass season. In large-scale ranch operations, including the supplementing of deficient range and of low-protein hay, about 100 pounds greater weight has been attained with as low as 200 pounds of extra feed.

These combined results justify certain statements: In California 200 to 300 pounds of supplemental feed given to younger cattle to promote continuous growth and efficient use of dry range or hay will very commonly result in about 100 pounds of additional weight. Such feed will replace about 500 pounds of concentrates and 400 to 500 pounds of harvested roughage required to make up this difference later in the feed lots. In other words, the time required for feed-lot finishing is reduced about half.

This over-all view of production from the calf to the final product, rather than a view of isolated production phases, is important. It considers not only the profit of the producer but also the maximum amount of human food that can be produced at the state or national level with the total feed available. In this experiment and others cited, a lifetime total of 1,400 to 1,738 pounds of concentrates has resulted in grade-A long yearling beef. Because of the soil type, the relatively short period when the feed is nutritious, and the acreage required per animal, this range must be considered a poor one from the standpoint of finishing cattle. The amounts of concentrates cited, however, are not in excess of those required to finish in feed lots cattle of similar age that have received no supplemental feed.

Judging from results, the total tonnage of beef produced from the feeds available for beef cattle in California could be tremendously increased through use of an increased proportion of the total for promoting continuous growth during the 3 to 6 months of the year when the forage on most ranges is nutritionally deficient or inadequate in quantity. The practice of allowing animals to gain and lose with the vagaries of climate and feed, although decreasing, is still all too common. The lower efficiency of using the supplements and concentrates only during a finishing period, either on range or in feed lots, is shown by the fact that less total beef is produced with the same quantity of feed.

The practicability of producing good-grade beef by a combination of sup-

TABLE 5

Carcass Data: Yield, Shrinkage, Yield of Wholesale Cuts, Carcass Values, and Composition of Rib Cuts

Group no.	Animal no.	Carcass yield, per cent*	Cooler shrinkage, per cent†	Hind quarters, per cent‡	Fore quarters, per cent	Whole round, per cent	Whole loin, per cent	Prime rib, per cent	Long plate, per cent	Shin and shoulder, per cent	Chuck, per cent
1	02	58.4	2.3	48.1	51.9	29.5	18.7	11.6	12.8	9.8	17.7
2	09	55.9	1.3	47.6	52.4	28.6	19.0	10.9	13.5	10.4	17.7
1	03	60.9	1.4	49.9	50.1	27.1	23.7	10.9	12.5	9.1	16.7
2	013	60.4	0.9	47.7	52.3	27.0	20.8	11.3	13.7	9.6	17.6
1	04	59.7	1.4	48.4	51.6	27.7	20.1	11.4	13.4	9.7	17.7
2	012	61.2	1.7	47.1	52.9	28.2	18.9	11.1	12.8	10.3	18.7
1	08	58.7	1.8	49.2	50.8	26.4	22.6	11.2	12.7	9.3	17.8
2	010	59.9	1.2	47.5	52.5	28.3	19.4	11.7	12.9	10.2	17.5
1	014	58.2	1.3	47.9	52.1	27.4	20.5	11.3	12.6	10.1	18.2
2	016	58.7	1.6	47.5	52.5	28.2	19.4	11.2	13.9	9.7	17.7
1	027	59.4	1.9	48.0	52.0	26.9	21.2	11.1	13.1	9.4	18.4
2	032	62.2	1.5	48.8	51.2	26.9	20.9	10.5	13.0	9.3	19.4
1	028	58.5	1.4	47.4	52.5	27.5	19.6	11.0	13.3	10.1	18.5
2	05	60.5	1.7	47.6	52.4	26.2	21.6	11.4	13.4	9.0	18.6
1	035	59.3	1.7	47.6	52.4	26.7	19.5	10.9	13.5	9.7	19.7
2	036	60.3	1.5	46.6	53.4	27.0	19.3	11.7	13.9	9.6	18.6
Group 1, average§		59.1	1.65	*48.3*	*51.7*	27.4	20.7	11.2	13.0	9.6	18.1
Group 2, average§		60.0	1.44	*47.5*	*52.5*	27.5	19.9	11.2	13.4	9.8	18.2

Group no.	Animal no.	Carcass weight, pounds	Carcass grade	Total value, dollars¶	Value per cwt. due to conformation, dollars‖	Composition of 12th and 13th rib cut			
						Fat, per cent	Lean, per cent	Bone, per cent	Lean in fat-free cut, per cent
1	02	514	Good	118.22	23.00	28.9	56.0	15.1	78.8
2	09	391	Commercial	81.84	22.93	24.1	57.6	18.3	75.9
1	03	569	Good	132.52	23.29	38.8	48.8	12.4	79.7
2	013	541	Good	124.48	23.01	35.2	48.6	16.2	75.1
1	04	612	Commercial	128.28	22.99	28.5	56.6	14.9	79.2
2	012	520	Commercial	108.78	22.95	21.9	61.8	16.3	79.1
1	08	640	Good	148.35	23.18	34.5	51.6	13.9	78.7
2	010	488	Commercial	102.43	22.86	28.0	55.7	16.3	77.4
1	014	541	Commercial	113.83	23.08	30.3	53.2	16.5	76.4
2	016	478	Commercial	100.04	22.94	32.8	52.5	14.7	78.4
1	027	573	Good	132.31	23.09	35.5	51.6	12.9	75.0
2	032	588	Good	135.18	22.99	33.6	51.6	14.8	77.6
1	028	559	Good	128.18	22.93	32.8	50.0	17.2	74.5
2	05	584	Good	134.79	23.08	35.8	49.5	14.7	77.0
1	035	578	Commercial	120.69	22.87	32.0	51.9	16.1	76.4
2	036	579	Good	132.59	22.90	35.5	52.5	12.0	81.4
Group 1, average§		*573*	....	127.79	23.05	32.7	52.4	14.9	77.9
Group 2, average§		*521*	....	115.02	22.95	30.9	53.7	15.4	77.8

* Computed on the basis of selling weight and carcass weight after 7 days in cooler.
† Computed from warm dressed weight and carcass weight after 7 days in cooler.
‡ No ribs were left on the hindquarters.
§ Italics indicate that the differences between group averages of basic data are statistically significant.
¶ Based on yield of wholesale cuts and price according to carcass grade.
‖ Based on yield of wholesale cuts and a standard price per pound for each cut. Variation, therefore, is caused by difference in proportion of the various cuts.

plemental and full-feeding on range is, moreover, demonstrated. This type of production should have a real place, particularly when competition for feed supply and labor is great: it produces more beef on the same feed by using it more effectively at earlier age; and it saves large quantities of harvested, baled, transported, and milled roughages necessary in feed-lot operations.

Growth and Development.—The average growth curves, figure 4, and the individual growth curves, figures 5 to 8, show a high correlation between changes in weight and changes in heart girth and round measurement. Skeletal development, on the other hand, as represented by height, body length, and head measurements, continued at a reduced rate in group 2 during the early part of period I. This increase occurred when body substance was being used to supplement the energy intake from the dry forage. When the animals were very thin and the feed still poorer in quality and less abundant, skeletal growth also came to a standstill.

At the end of period I, animals of group 2 lacked development. They appeared to have relatively longer legs, slimmer and shallower bodies, and lighter rear quarters, which gave them the appearance of poorer-bred cattle. Comparisons at this time are shown in the photographs taken December 30, 1941 (plates 1 to 7).

Although, by range standards, group 2 could not be considered weak at the end of period I, the ease with which the hindquarters could be pushed from side to side in the chute and the flabbiness of the shrunken thigh muscles observed in the taking of round measurements were particularly striking. The difference in the animals after supplements had been given for 5 weeks was very impressive. The muscles felt firm and plump, with normal tonus; and a conspicuous increase in measurement was shown.

Under the conditions of this experiment there was no conspicuous change in the proportionate growth of length and width of heads. In McMeekan's studies of swine (1940–1941) the animals were permitted to grow at reduced rates for long periods and increased in bone length at the expense of bone thickness; heads became longer in relation to width. This is doubtless the explanation for observed fineness of bone in cattle developed on poor ranges. The earlier in life the privation occurs, the more striking is the result. Hammond (1933) has shown that growth occurs in three overlapping phases, the peak of bone growth preceding that of muscle, and muscle growth preceding the peak of fat deposition.

Carcass Differences.—The difference in average carcass weight between group 1 and group 2 shown in tables 4 and 5 was 52 pounds and is statistically significant. In five of the eight pairs of animals there was a wide difference in carcass weights. Carcass weights were equal in one pair, and group 2 animals slightly exceeded their group 1 mates in two cases. Although the animals had been carefully selected for uniformity of pairs, these and other data show that there were genetic differences between them. Some were affected more than others by privation, and there were evidently individual differences in ability to respond to favorable environment.

Although in five out of eight pairs, group 1 animals were fatter as indicated by the percentage fat in the rib cuts, and the group average was slightly higher for group 1, the average difference was not statistically significant. In two of

three pairs in which carcass weight was equal or slightly greater in group 2 animals, the latter had the higher fat percentage. This situation might have been expected from the results McMeekan (1940–1941) obtained with his low-high group. To secure equal average group weights at the close of the experiment, it would have been necessary to full-feed group 2 as was done and allow group 1 to continue on grass alone from June to September, 1942. Since group 1 was only in fleshy-feeder condition in June and no further net gain could have been expected on grass alone, the average result would necessarily have been similar to that in McMeekan's high-low and low-high groups. That is, group 1 carcasses would have been high in lean compared with fat, whereas group 2 would have averaged much fatter at the same average weight.

The small but statistically significant difference in hindquarter yield of group 1 as compared with group 2, shown in tables 4 and 5, agrees with the results of the Missouri and Cambridge experiments. Evidently, higher planes of nutrition, particularly at the earlier ages, stimulate development of later-maturing parts. Increasing fatness also tends to increase the proportion of hindquarter weight.

Although the differences were not statistically significant, it is interesting that the average shipping shrinkage of group 2 was less than that of group 1 in six of the eight pairs. Despite this and the fact that average fatness was less, group 2 averaged slightly higher in dressing percentage. At the time of the last measurements group 2 had slightly less paunch girth in relation to heart girth than group 1.

Although group 1 averaged higher in per cent of fat and lower in lean and bone of the rib cuts than group 2, the differences are not significant. There was no difference in the proportion of lean to bone in the fat-free cuts (table 5). Apparently whatever changes may have occurred during the period of privation suffered by group 2, the animals recovered under favorable conditions and ultimately had relative amounts of bone and lean comparable with group 1. The differences noted in the proportion of lean and bone in the whole cut were caused by fat variation.

The carcass value per hundredweight was computed by multiplying the percentage of each cut by the following prices per hundredweight:

	Good grade	Commercial grade
Whole rounds	$24.00	$22.00
Whole loins	29.00	25.00
Prime rib	25.00	23.00
Long plate	14.50	14.00
Shin and shoulder	22.50	20.50
Chuck	20.00	19.00
Average	$23.00	$21.00

The averages were the ceiling prices for good and commercial whole carcasses at the time of slaughter. The proportionate prices of cuts are believed to be reasonably well in line with general practice, though they vary considerably, depending on demand and on method of cutting.

Total value of each carcass was derived by multiplying average carcass

value per hundredweight by the carcass weight and thus includes variations due both to grade and to conformation.

Table 6 presents data on some of the more important items that contribute to the value of the animals and carcasses. The animals are listed without respect to group and in order of degree of fatness as indicated by analysis of the rib cut.

TABLE 6

Comparison of Various Marketing, Slaughter, and Carcass Data
(Arranged in order of increasing fat content of rib cuts)

Animal no.	Live animal grade*	Official U. S. carcass grade	Packer carcass grade	Live animal price per hundred-weight	Per cent fat in rib cut	Carcass value due to grade and conformation per cwt.†	Carcass value due to conformation alone per cwt.‡	Dressing, per cent
012	Commercial	Commercial	Commercial	$12.50	21.9	$20.92	$22.92	61.2
09	Commercial+	Commercial	Commercial	12.50	24.1	20.93	22.93	55.9
010	Commercial+	Commercial	Commercial	13.50	28.0	20.99	22.86	59.9
04	Good	Commercial	Good	14.00	28.5	20.96	22.99	59.7
02	Commercial+	Good	Good	13.50	28.9	23.00	23.00	58.4
014	Commercial+	Commercial	Good	14.00	30.3	21.04	23.08	58.2
035	Good	Commercial	Good	14.00	32.0	20.88	22.87	59.3
028	Commercial+	Good	Good	13.50	32.8	22.93	22.93	58.5
016	Good−	Commercial	Good	13.50	32.8	20.93	22.94	58.7
032	Good−	Good	Good	14.00	33.6	22.99	22.99	62.2
08	Good+	Good	Good	14.00	34.5	23.18	23.18	58.7
013	Good	Good	Good	14.00	35.2	23.01	23.01	60.4
036	Good	Good	Good	14.00	35.5	22.90	22.90	60.3
027	Good	Good	Good	14.00	35.5	23.09	23.09	59.4
05	Good	Good	Good	14.00	35.8	23.08	23.08	60.5
03	Good+	Good	Good	$14.00	38.8	$23.29	$23.29	60.9

* The signs + and − indicate top and low end of grade respectively.
† See text for wholesale cut prices.
‡ Prices for good grade were used throughout in these calculations. Value per hundredweight variation is therefore due solely to differences in proportion of various cuts.

There was perfect agreement in the grading of the live animals, the buying price, and the carcass grade in the first three animals (fat content 28 per cent and under) and in the last seven (fat content 33.6 to 38.8 per cent). Animals 04 to 016 inclusive ranged between 28.5 and 32.8 per cent fat in the rib cut, were borderline between good and commercial, and caused considerable variation in judgment. Carcass value per hundredweight due to both grade and conformation is shown, and also variation due to conformation alone. For these latter calculations the price for good grade was used throughout and was applied to the percentage yield of cuts of each carcass. The maximum difference in value due to conformation (proportion of wholesale cuts) was 43 cents per hundredweight, a difference of 1.9 per cent. Since all these animals were considered to be within the limits of the range of one grade as feeders, no great difference might be expected.

Largely because of higher yield of hindquarter in group 1, the average value due to conformation was slightly higher in this group (table 5).

Dressing percentage in general tended to increase with the fat content. Size

of middle and amount of fill were also important factors causing variation. No. 012, the very nervous steer, had little fill and second highest carcass yield, although he was the least fat.

Lush (1926) and workers in the U. S. Department of Agriculture Bureau of Animal Industry (Black and co-workers, 1940) found high correlation between the percentage of fat in the edible portion of rib cuts and the percentage of fat in the entire carcass; they developed formulas for estimating the latter from the former. Total carcass fat content in this experiment was calculated by means of the Bureau of Animal Industry equation: The percentage of fat (ether extract) in the edible portion of the carcass is 0.738 times the percentage of fat (ether extract) in the edible portion of the 9th, 10th, and 11th rib cut plus 3.56 per cent.

According to these calculations the carcasses that all graders agreed were commercial (nos. 012 to 010 inclusive, table 6) varied from 22.9 to 28.2 per cent fat in the edible portion of the carcasses; those that were borderline, with incomplete agreement (nos. 04 to 016 inclusive), varied from 29.3 to 31.3 per cent; those that all graders regarded as good grade (nos. 032 to 03 inclusive) varied from 32.7 to 36.2 per cent fat.

No data are available to show that the 12th and 13th rib cuts used in the present experiment are strictly comparable in composition with the 9th, 10th, and 11th rib cuts, upon which the equation above is based. Since the loin normally contains more fat than the prime ribs, one might expect the rib cuts nearest the loin to contain somewhat more fat. Black and his co-workers (1940) estimated the fat in carcasses according to this formula. They obtained average values of 23.94 to 31.09 per cent for groups of steers varying in carcass grade from average commercial to average good. Chatfield (1926) estimated that commercial carcasses varied between 18 and 25 per cent fat in the edible portion, and good-grade carcasses from 25 to 35 per cent. Judging from these results, further data are required before one can rely on the fat content of the 12th and 13th rib cuts for estimating fat in the entire carcass. These cuts were used in the present work because of the Pacific Coast practice of leaving all ribs on the forequarter and because of the convenience and economy of using the first two-rib cut.

SUMMARY AND CONCLUSIONS

The experiment was designed to obtain data on the effectiveness of supplemental feed supplied at different periods of the year and at different stages of development of the animals—factors that influenced the shape of their growth curves. Data on costs, gains, and the carcass quality were obtained.

The sixteen steers to be finished as yearlings were selected from the San Joaquin Experiment Range herd at weaning time (July 1, 1941) and were divided into eight closely matched pairs, distributed equally into groups 1 and 2. The time interval of slightly over 14 months (July, 1941, to September, 1942) was divided into three periods: first, the dry-feed period from July to January; second, the green-feed period from January to June; third, a finishing period from June to September 7, when both groups were full-fed concentrates on dry forage.

The main difference in management consisted in feeding group 1 steers con-

centrate supplements through period I so that they gained about 1 pound daily, whereas group 2 (in accordance with common practice) subsisted on range feed alone, and lost weight. In period II, group 1 received range feed only and, after a short period when green forage was scant and high in moisture, continued to gain. Group 2, on the other hand, now received concentrate supplements with range feed and made greater gains. As is well recognized, steers that maintain or lose weight in the dry-feed or winter season will gain faster during the following green-feed season than comparable groups that have made continuous gain induced by supplemental feeding. In this experiment, feeding supplements to previously deprived animals in group 2 enhanced their gain during period II. Group 1 gained an average of 182 pounds during this period and at its close weighed 860 pounds, as compared with a gain of 304 pounds and an average weight of 765 pounds for steers of group 2. In period III both groups were full-fed concentrates on the range at the rate of approximately 1 pound per 100 pounds live weight.

As a result of difference in management practice, group 1 returned $17.51 more per head, whereas the supplemented feed cost was only $1.40 greater, only 70 pounds more concentrates having been consumed by them than by group 2. This result was due to an average of 108 pounds greater live weight, 52 pounds greater carcass weight, and a somewhat higher selling price for group 1.

During the 14-month period, changes in body size and proportions were recorded by means of weights, body measurements, and photographs. Data on grades and proportions of wholesale cuts for each carcass showed on the average that group 1 animals had the advantage.

Their greater efficiency was due to comparatively small daily allowances of supplement. These allowances permitted efficient utilization of the nutritionally deficient dry forage in period I, thereby promoting continuous growth when the stimulus was greatest and decreasing the proportion of feed utilized for maintenance. According to these and other data, 200 to 300 pounds of supplemental feed used at earlier ages will in California commonly result in 100 pounds of additional weight and in a higher selling price for feeders. It will, furthermore, save about 500 pounds of concentrates and 400 to 500 pounds of harvested roughages necessary to make up this difference later in feed lots. Thus, in California, advantage would be derived if feeds available for beef cattle were used in greater proportion to supplement range, and relatively less feed would then be required for finishing in feed lot. As the data also demonstrate, a combination of supplemental feeding for continuous growth, followed by a finishing period on range with concentrates full-fed, can produce grade-A long yearling beef. This saves the labor involved in the harvesting, baling, transporting, and milling of roughages—a consideration particularly important in wartime.

Many better California ranges will yield superior finish with less concentrates than the San Joaquin Experimental Range.

During their period of privation, group 2 animals had relatively longer legs, slimmer shallower bodies, and lighter rear quarters with finer bone, which gave them the appearance of poorer-bred animals. Skeletal growth continued during the early part of the period, but practically ceased toward the end.

At the conclusion of the experiment there was no significant difference in average fatness of the two groups. Group 1 yielded relatively more hindquarter than group 2. These results agree with swine and sheep data cited, which show that a high plane of nutrition early in life followed by a lower plane results in carcasses higher in lean and lower in fat than when the reverse occurs, even though the same final weight at the same age is obtained. The data support the evidence that high planes of nutrition speed up the development of thickness growth generally, especially in later-maturing parts such as loin and hindquarter.

According to analysis of rib cuts from each carcass, on a fat-free basis, there was no difference in proportion of lean to bone between the two groups.

From the standpoint of total feed required to produce a unit of product, greatest efficiency is obtained from a high plane of nutrition, with continuous growth and development. The degree of approach to the ideal that may be made under specific conditions depends upon the relative costs of different phases of production—for example, cost of summer gain on range compared with winter gain on hay. Particularly when maximum production is being stressed, one should consider the birth-to-slaughter feed requirement and the feed used at the stages and in the amounts that will yield greatest over-all efficiency. When this broad view is taken, there is a high correlation between biological efficiency and dollars-and-cents economy.

The principles and objectives brought out in this experiment may be realized in ways other than the feeding of concentrate supplements. To secure continuous growth and development one may, for example, make coördinated use of native forage and irrigated pasture; or one may improve the quality of hay by including legumes and by cutting and curing the hay in a manner that will preserve its nutritive value; or one may adopt better methods of feeding. Any consideration of efficiency of beef production must begin with the cow herd, the percentage calf crop, and the weaning weight. Adaptation of creep-feeding practices to special conditions is another possible way of increasing low-cost gain.

The experiment reported was designed primarily to illustrate a principle rather than to indicate an exact practice. A six-year program is under way at the San Joaquin Experimental Range to obtain detailed information on the most practical methods for range finishing of long-yearling steers. This involves the amount of feed and the most efficient rate of gain from weaning until the next grass season; the question of feeding concentrates during the green-forage season or of full-feeding at the end of this season; and, finally, the best combination of practices for the three phases of this type of production program. Each livestock producer should make such adaptations of these principles as his individual situation makes practical.

LITERATURE CITED

Black, W. H., J. R. Quesenberry, and A. L. Baker.
1939. Wintering steers on different planes of nutrition from weaning to 2½ years of age. U. S. Dept. Agr. Tech. Bul. **667**:1–20.

Black, W. H., R. L. Hiner, L. B. Burk, L. M. Alexander, and C. V. Wilson.
1940. Beef production and quality as affected by methods of feeding supplements to steers on grass in the Appalachian Region. U. S. Dept. Agr. Tech. Bul. **717**:1–32. 7 figs.

Chatfield, C.
1926. Proximate composition of beef. U. S. Dept. Agr. Dept. Cir. **389**:1–18.

Gregory, P. W.
1933. The nature of size factors in domestic breeds of cattle. Genetics **18**:221–49.

Guilbert, H. R., L. W. Fluharty, and V. M. Shepard.
1943. California beef production data. California Agr. Exp. Sta. Lithoprint Leaflet. 6 p.

Guilbert, H. R., and H. Goss.
1944. Digestibility of range forages and flax hulls. California Agr. Exp. Sta. Bul. **684**:1–10.

Hammond, J.
1933. How science can help improve the nation's food supply. Soc. Chem. Indus. Jour. **52**:637–40.
1940. Farm animals: their breeding, growth and inheritance. 199 p. (See specifically p. 88.) Longmans, Green and Co., New York, N. Y.

Hutchison, C. B., and E. I. Kotok.
1942. The San Joaquin Experimental Range. California Agr. Exp. Sta. Bul. **663**:1–145.

Lush, J. L.
1926. Practical methods of estimating the proportions of fat and bone in cattle slaughtered in commercial packing plants. Jour. Agr. Res. **32**:727–55.

McMeekan, C. P.
1940–1941. Growth and development in the pig, with special reference to carcass quality characters. Jour. Agr. Sci. **30**:276–337; **31**:1–161.

Moulton, C. R., P. F. Trowbridge, and L. D. Haigh.
1921. Studies in animal nutrition. I. Changes in form and weight on different planes of nutrition. Missouri Agr. Exp. Sta. Res. Bul. **43**:1–111. 30 figs.
1922*a*. Studies in animal nutrition. II. Changes in proportions of carcass and offal on different planes of nutrition. Missouri Agr. Exp. Sta. Res. Bul. **54**:1–76. 28 figs.
1922*b*. Studies in animal nutrition. III. Changes in chemical composition on different planes of nutrition. Missouri Agr. Exp. Sta. Res. Bul. **55**:1–88. 20 figs.

Trowbridge, P. F., C. R. Moulton, and L. D. Haigh.
1915. The maintenance requirement of cattle. Missouri Agr. Exp. Sta. Res. Bul. **18**: 1–62. 17 figs.
1918. Effect of limited food on growth of beef animals. Missouri Agr. Exp. Sta. Res. Bul. **28**:1–129. 23 figs.
1919. Composition of the beef animal and energy cost of fattening. Missouri Agr. Exp. Sta. Res. Bul. **30**:1–106. 25 figs.

Verges, J. B.
1936. The effect of nutrition on the carcass quality of Suffolk cross lambs. Suffolk Sheep. Soc. Yearbook, Ipswich. (Original not seen; cited by Hammond, 1940.)

Wagnon, K. A., H. R. Guilbert, and G. H. Hart.
1942. Experimental Herd Management. *In:* Hutchison, C. B., and E. I. Kotok. The San Joaquin Experimental Range. California Agr. Exp. Sta. Bul. **663**:50–82.

Watson, D. M. S.
1943. Beef cattle in peace and war. Empire Jour. Exp. Agr. **11**:191–228.

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